CONCISE ENCYCLOPEDIA OF PLASTICS

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Plastics FALLO

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Dominick V. Rosato has been involved worldwide principally with plastics since 1939, from designing through fabricating through marketing products from toys through commercial electronic devices to aerospace products. His experience includes work at the Air Force Materials Laboratory (where he headed Plastics R&D), Raymark (where he was Chief Engineer), and Ingersol-Rand (where he served as International Marketing Manager), and he has lectured worldwide. He has received various prestigious awards from U.S. and international associations, societies, publications, companies, and the National Academy of Science and has authored nineteen books. He holds a BS in Mechanical Engineering from Drexel University, with advanced training at Yale University.

Marlene G. Rosato has very comprehensive international plastics and elastomer business experience in technical support, plant start-up and troubleshooting, manufacturing and engineering management, business development, and strategic planning with Bayer/Polysar and DuPont and does extensive international technical, manufacturing, and management consulting for Plastics FALLO and PlastiSource Inc. She received a Bachelor of Applied Science in Chemical Engineering from the University of British Columbia and has had extensive executive management training.

Donald V. Rosato has extensive technical and marketing plastics industry business experience from laboratory testing, through production to marketing, having worked for Northrup Grumman, Owens-Illinois, DuPont/Conoco, Hoechst Celanese, and Borg Warner/G.E. Plastics. He has written extensively, developed numerous patents within the polymer related industries, is a participating member of many trade and industry groups, and currently is involved in these areas with PlastiSource, Inc., and Plastics FALLO. His degrees include a BS in Chemistry from Boston College, an MBA from Northeastern University, an M.S. in Plastics Engineering from University of Massachusetts Lowell (Lowell Technological Institute), and a Ph.D. in Business Administration from the University of California, Berkeley.

Preface

After over a century of worldwide production of all kinds of products, the plastics industry is now the fourth largest industry in the United States. This brief, concise, and practical book is a cutting edge compendium of the plastics industry's information and terminology—ranging from design, materials, and processes, to testing, quality control, regulations, legal matters, and profitability. New and useful developments in plastic materials and processing continually are on the horizon, and the examples of these developments that are discussed in the book provide guides to past and future trends.

This practical and comprehensive book reviews the plastics industry virtually from A to Z through its more than 25,000 entries. Its concise entries cover the basic issues (such as plastic's melt flow behavior during processing) as well as advanced issues (such as the design and fabrication of products that are targeted to meet performance and cost requirements with zero defects).

Extensive crossreferences—between a subject's definition and the many other subjects it relates to—contribute significantly to keeping the book to a manageable size. Readers can search for either a major definition or its cross-referenced components, depending on need. This approach helps to simplify understanding of any single subject and highlights the many similarities and interactions that exist among subjects in the World of Plastics.

This book is a guide to understanding the worldwide technology and business of plastics—how to design, prototype fabricate, and volume manufacture the many different marketable plastic products that exist worldwide. The book can help readers apply the correct performance and safety factors that ensure that plastics continue to be processed successfully—with high quality, consistency, and profitability. As such, it helps people who are not familiar with plastics to grasp the benefits and advantages of plastics. It also can enhance the intuitive skills of those people who are already working in plastics. The theorist, for example, can gain insights into the limitations of plastics relative to other materials, such as steel and wood. In short, the book is useful for both technical and nontechnical readers—such as people working in production, managers, engineers, designers, marketers, educators, trainers, salespeople, venture capitalists, lawyers, workshop leaders, librarians, information providers, testing and quality control persons, cost estimators, buyers, vendors, consultants, and others.

The bulk of the book is the alphabetical listing of entries. Preceding those entries is A Plastics Overview: Figures and Tables (which presents eight summary guides on the subjects examined in the text) and then the World of Plastics Reviews (which presents 14 articles that provide general introductory information, comprehensive updates, and important networking avenues within the world of plastics). Following the alphabetical listing of entries, at the end of the encyclopedia, seven appendices provide background and source guide information keyed to the text of the book. The extensive and useful Appendix A, List of Abbreviations, lists all abbreviations used in the text.

This book predominantly uses the word *plastic* to refer to polymer, resin, elastomer, and so on because most of the industry worldwide uses this term. It uses the term *reinforced plastic* to refer to composite, laminate, and so on.

Limited information on the material properties of plastics is provided as a comparative guide. Readers can obtain the latest information from suppliers and industry software. Our focus in this book is to present, interpret, analyze, and interrelate the basic elements of plastics fabrication and industry. Even though more than 17,000 plastic materials exist worldwide (some estimates are as high as 50,000), selecting the right plastic requires applying certain factors such as setting up performance target requirements, choosing and adapting the process to be used, and intelligently preparing a specification purchase document and work order. New developments in plastic materials, requiring updates, are always on the horizon. Some plastics meet high performance requirements such as long time-creep resistance, fatigue endurance, toughness, and so on. Others are volume and cost driven in their use.

Examples of subjects include: additive, adhesive, alloying, amorphous plastic, ASTM, auxiliary equipment, bag molding, barrel analysis, barrier material, biodegradable, blending, blow molding, business, calendering, casting, catalyst, certification, chemical structure, clamping, coating, coefficient factor, coextrusion, coinjection, color, compounding, compression molding, computer analysis, control, cost, creep, crystalline plastic, curing, data (theoretical and actual), decomposition, decorating, defect, design analysis, die, directional property, dynamic condition, drying, dye, economic, elastomer, electrical, electronic, encapsulation, energy, environment, extruder (film, sheet, coating, etc.), fabricating process, failure analysis, fatigue, fiber type and process, filament winding, filler, fire, fluidized bed coating, foam, friction, fusion, gauge, GDP, gelation, glass transition, graphite, hazard, heat resistance, hydraulic, hysteresis, impact behavior, incineration, injection molding (solid, gas, foam, etc.), inspection, IR behavior, ISO, joint behavior, legal matter, light behavior, machining, maintenance, manufacture, market, material handling, melt behavior and characteristic, metal, metallocene catalyst, mixer, modeling, modulus, mold, molding, molecular behavior, morphology, motion control, myth/fact, natural, nondestructive test, nonwoven fabric, orientation, packaging, paint, patent, pelletizing, people, perfection, pigment, plant operation, plasticator, plastic consumption, plastic type and characteristic, plastisol, polymerization, postforming, preform, prepreg, pressure characteristic, printing, problem & solution, process control, processing type, processor, product, productivity, profit, property (mechanical, physical, chemical, optical, etc.), prototype, purging, quality characteristic, radiation, reaction injection molding, recycling, reinforced plastic, reinforcement, resin transfer molding, rheology, risk, rotational molding, rubber, safety, safety factor, sandwich, screw analysis, sensor, servo control, shrinkage, software, solvent, specification/standard, spraying, statistic, sterilization, storage, surface finish, synthetic, temperature analysis, testing, thermal analysis, thermoforming, thermoplastic, thermoset plastic, tolerance, tooling, training, troubleshooting, ultrasonic device, UV characteristic, vacuum process, viscoelasticity, viscosity, volatile, vulcanization, waste, weatherability, welding, wood/plastic, woven fabric, yield characteristic, zero defect, and so on.

No authorization to utilize the patents or trademarks cited in the book is given or implied. The use of general descriptive names, proprietary names, trade names, commercial designations, or the like does not in any way imply that they may be used freely. They are discussed for information purposes only. While information presented is believed to be true and accurate, neither the authors nor the publisher can accept any legal responsibility for any errors, omissions, inaccuracies, or other factors.

In preparing this book and ensuring its completeness and accuracy, the authors drew on their personal industrial and teaching experiences, as well as on information made available by industry associations, industry contacts, industry conferences, and books and articles written about plastics. We wish to thank the countless people who have contributed to the World of Plastics in various capacities over many years—and who thereby made possible the publication of this encyclopedia.

Donald V. Rosato
Marlene G. Rosato
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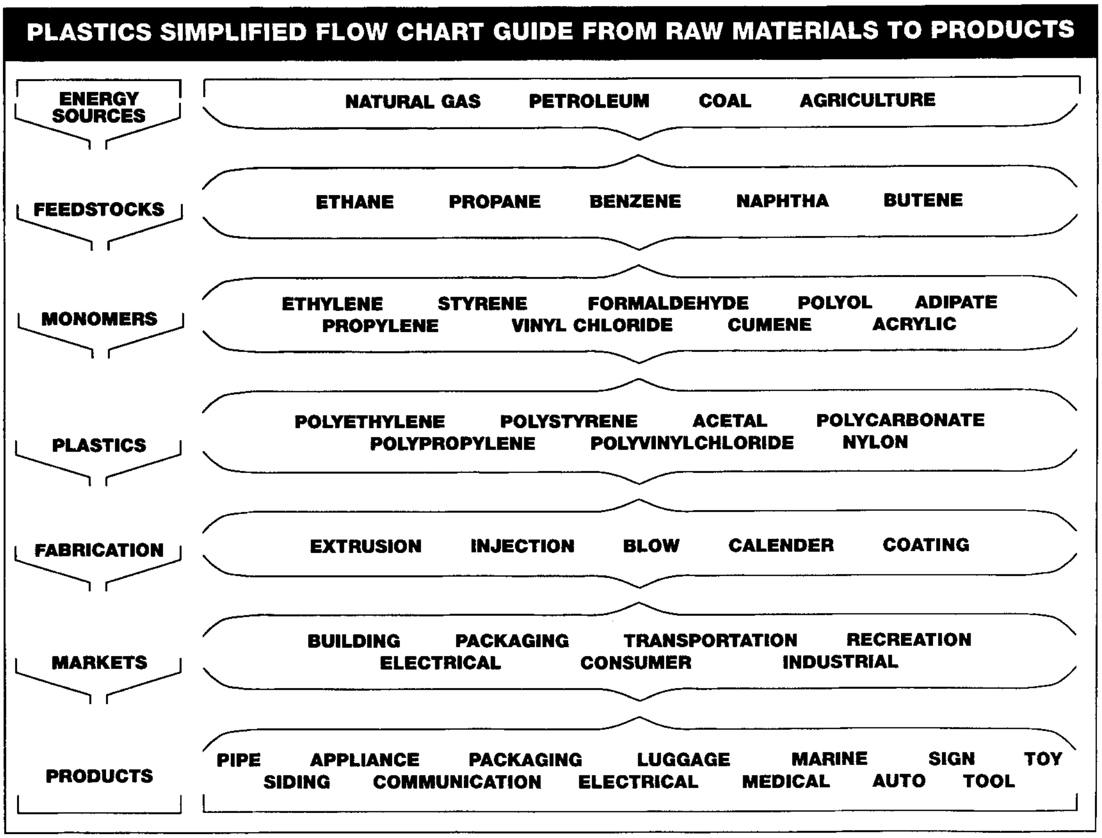


Fig. 1. Plastics Simplified Flow Chart Guide from Raw Materials to Products. (Source: PlastiSource, Inc.)

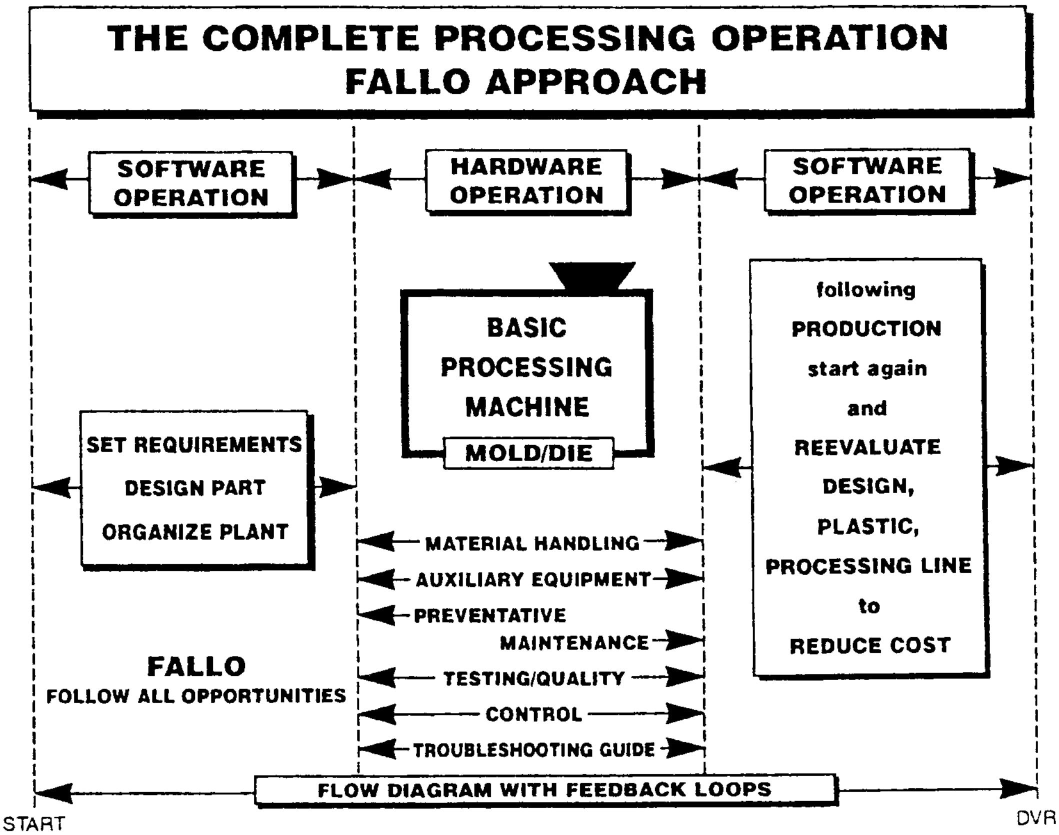


Fig. 2. The Complete Processing Operation. (Source: Plastics FALLO/DVR.)

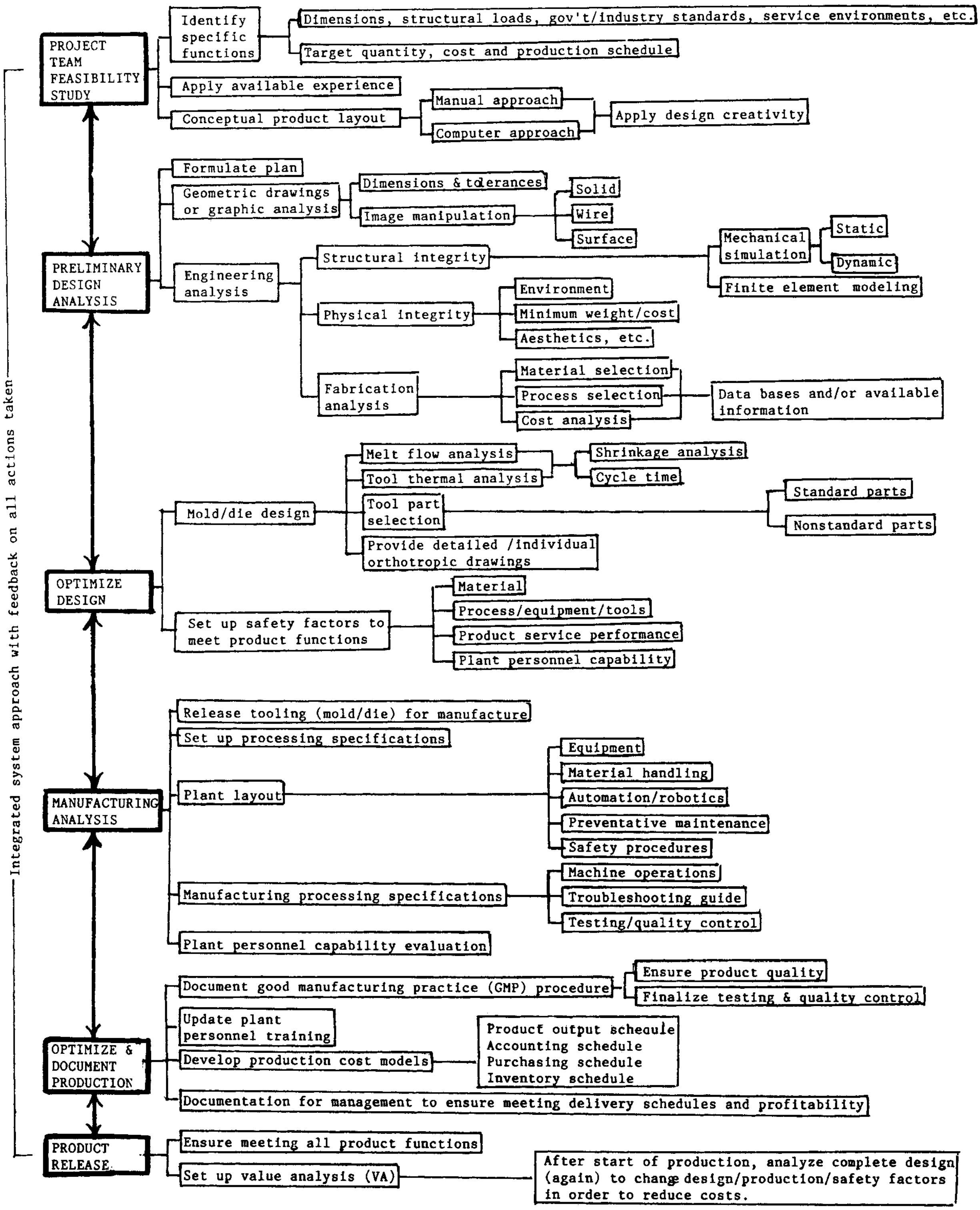
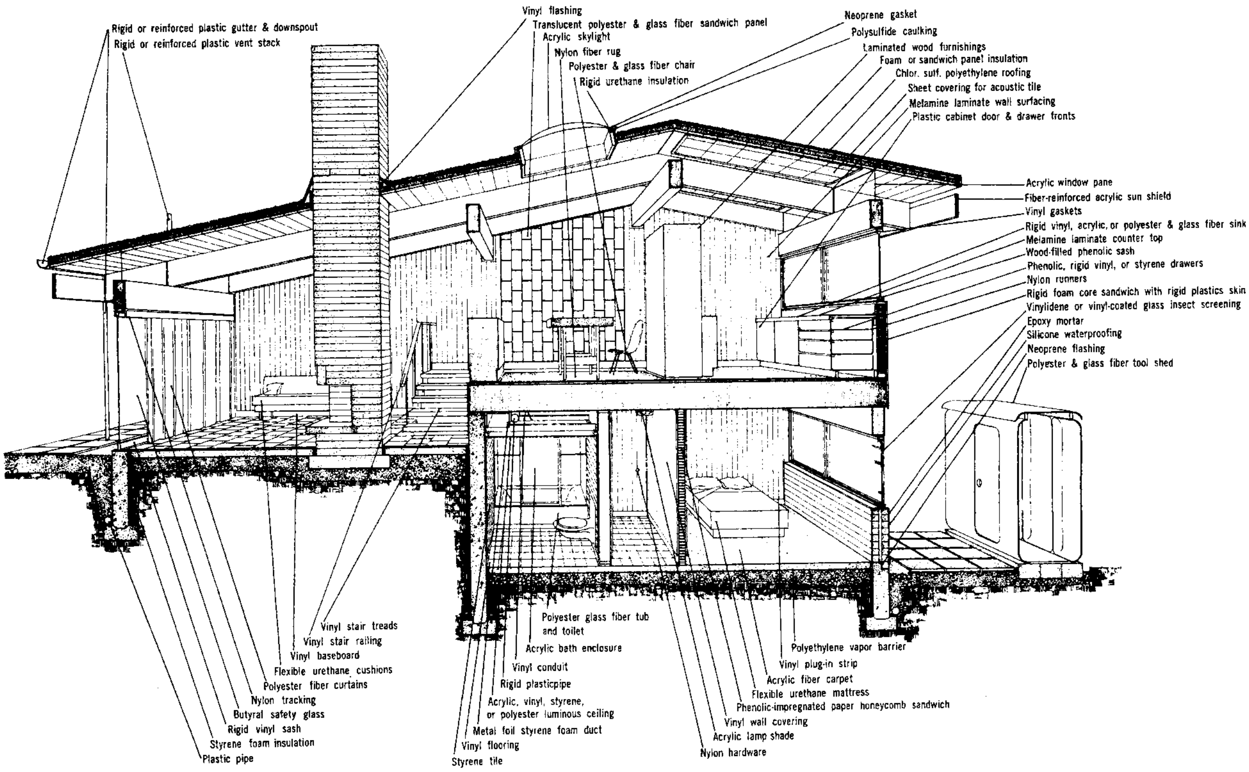


Fig. 3. Design Flow Diagram to Produce Products. (Source: DVR.)



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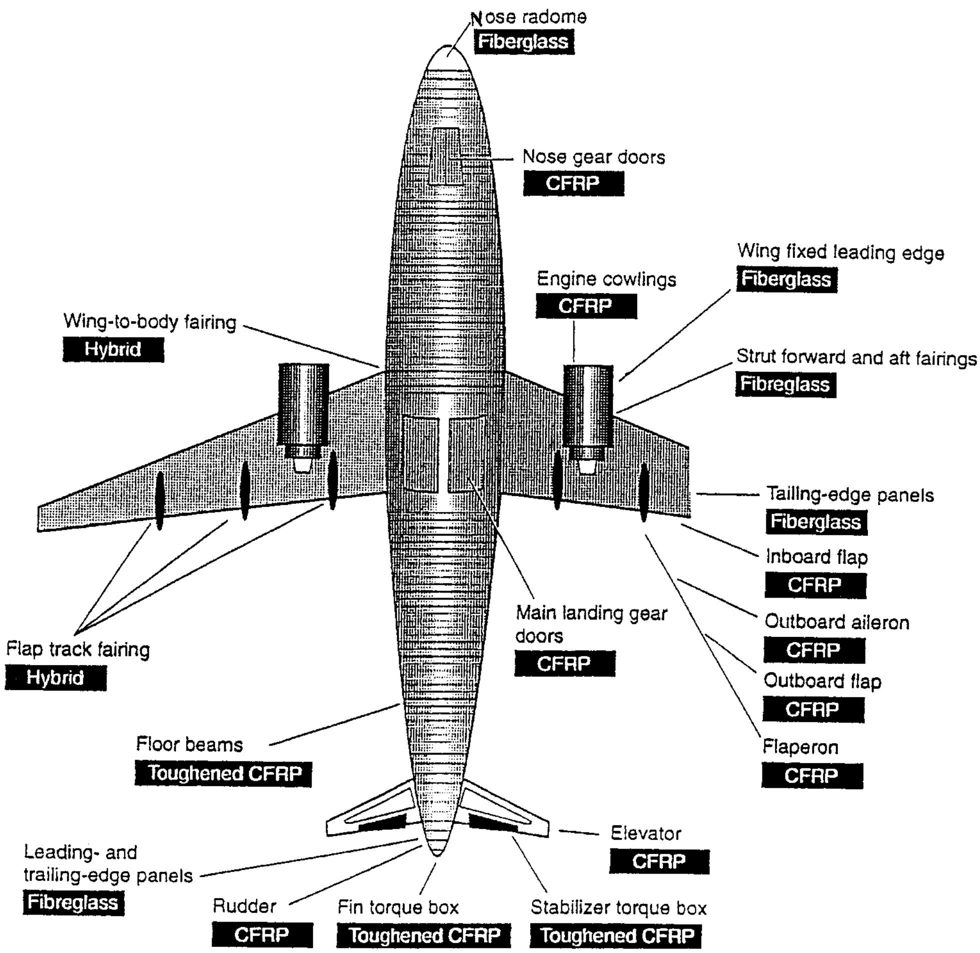

Fig. 5. Examples of Reinforced Plastics on the Boeing 777. (Source: Boeing, Inc.)

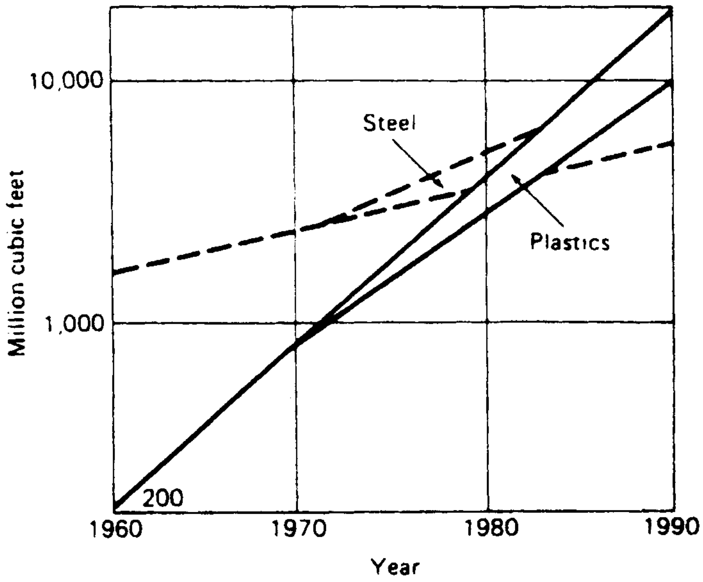

Fig. 6. World Consumption of Plastics by Volume. (Source: DVR/Plastics FALLO.)

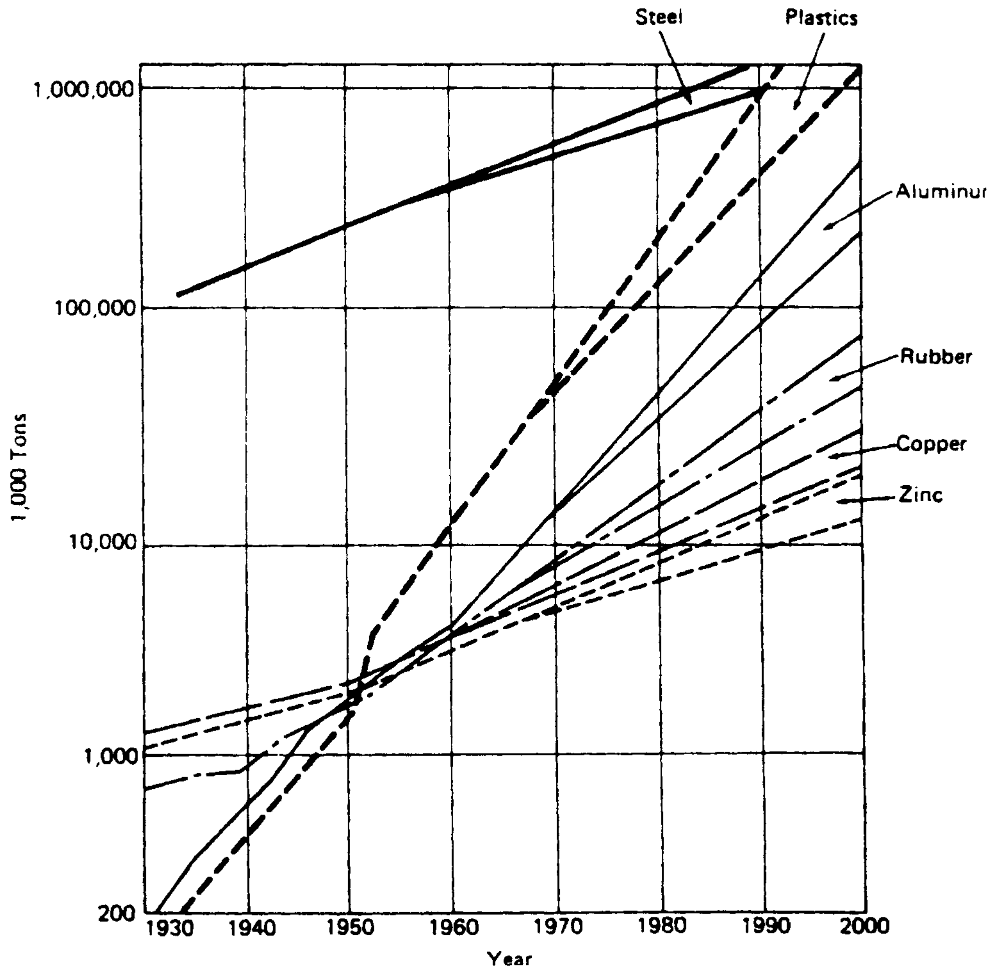

Fig. 7. World Consumption of Plastics by Weight. (Source: DVR/Plastics FALLO.)

Table 1. World Plastics Consumption in Year 2000 (millions of pounds).

Plastic	United States	Canada	Mexico	Brazil	Other Latin America[a]	Western Europe[b]	Eastern Europe[c]	Japan	China	Other Asia-Pacific[d]	Africa and Middle East	Rest of World	Grand Total
LLDPE	8,468	610	480	610	900	4,093	1,023	1,439	2,661	6,121	580	367	27,352
LDPE	7,748	1,281	1,176	1,590	619	10,254	2,563	1,804	1,938	3,391	1,210	457	34,031
HDPE	14,065	1,136	952	1,388	417	9,178	2,294	2,158	1,218	4,967	1,325	532	39,630
Urethane	5,265	475	380	410	390	5,481	1,808	1,512	1,825	4,850	390	310	23,096
PVC	14,698	1,394	605	1,456	1,837	12,388	2,477	3,761	5,338	11,633	1,250	773	57,610
Polystyrene	6,589	725	405	280	495	6,180	1,236	2,175	2,299	5,275	190	352	26,201
Polypropylene	13,739	796	695	1,366	1,307	13,566	2,713	5,001	2,667	11,176	1,275	738	55,039
ABS	1,409	145	175	365	290	1,410	282	948	460	950	305	92	6,831
Acrylic	613	75	80	165	140	576	115	302	155	325	140	37	2,723
Unsaturated polyester	1,681	180	125	250	210	1,036	207	1,285	645	1,175	215	95	7,104
Nylon	1,267	110	90	170	145	1,210	242	339	170	425	155	59	4,382
PET	4,330	410	192	482	386	2,464	493	1,178	715	5,441	390	224	16,705
Polycarbonate	857	90	70	155	140	607	121	443	215	475	145	45	3,363
Thermoplastic polyester	346	45	30	65	50	243	48	164	85	322	42	20	1,460
Acetal	389	40	30	70	45	317	63	212	106	235	63	21	1,591
Recycled plastics	1,800	166	121	195	162	1,625	220	502	453	1,254	165	88	6,751
Other plastics[e]	8,150	763	412	875	74	7,250	1,750	255	198	5,310	740	344	26,121
Total	91,414	8,441	6,018	9,892	7,607	77,878	17,655	23,478	21,148	63,325	8,580	4,554	339,990

Source: Modern Plastics/PlastiSource Estimates/DVR.

[a] Argentina, Chile, Colombia, Venezuela, and all other. [b] European Union plus Norway and Switzerland. [c] Includes Russia and the Balkans. [d] Australia, India, Indonesia, Malaysia, North Korea, Pakistan, South Korea, Taiwan, Thailand, Philippines, Singapore, and Vietnam. [e] High performance, other thermosets, specialty elastomers, tailored blends, and alloys.

WORLD OF PLASTICS REVIEWS

The following articles provide an overview of the World of Plastics. This background information introduces the comprehensive view in the text of this book and permits readers to interrelate the many different subjects discussed in the text, from raw materials to the fabricated products.

THE PLASTICS PHENOMENON

Michael R. Cappelletti, Executive Director, Society of Plastics Engineers, 14 Fairfield Drive, Brookfield, CT 06804, telephone 203-775-0471, website: www.4SPE.org

The enterprise that plastics and the plastics industry have formed is nothing short of phenomenal. An entirely new industry emerged creating employment for an estimated 5 million people worldwide. The plastic products produced and used worldwide have made a major contribution to the progress of materials and civilization. The industry is too young to begin to surmise its final direction.

The plastics industry is experiencing interesting shifts in direction through globalization, consolidations, the increased demand for information, and the drive for quality. The Internet has fueled an information explosion, drastically altering how we obtain the data and information necessary for successfully continuing the expanding growth of our industry. These changes give rise to opportunities that are imperative for survival today. No longer do suppliers stand alone. They are now an important part of the task forces designed to shepherd products through the value chain—designing, manufacturing, and meeting all kinds of performance and cost requirements.

Alliances have been created worldwide as the need to exchange information grows. Not long ago collaborating with business partners in such places as China, South America, South Africa, and the Pacific Rim would have been impossible, but today global marketing is a prerequisite for corporate success.

Crossing one's fingers and hoping for survival in this new millennium will not be enough to ensure that survival. An entire workforce needs continuing education to handle the expansion of the existing industry and the new developments always on the horizon. As the industry grows, science and technology will meet the challenges and opportunities to create new materials, new processing techniques, and solutions to new technical and marketing problems.

The Society of Plastics Engineers has been gathering information to help its worldwide members obtain the skills necessary to flourish in this exciting future. We provide our members with the means to better understand this industry and the products and service the industry demands. We have decided to shift from a "make and sell" mass-production paradigm to a "sense and respond" mass-customized paradigm. Our staff has been reorganized from a silo configuration into high-performance teams, thus aligning our initiatives directly with our strategic plan. New programs have been launched that target the specific needs of our members and customers.

As we journey into the next millennium, SPE continues to serve as the preferred provider of technical and business information for the entire plastics industry.

SPI: THE INDUSTRY'S VOICE

Donald K. Duncan, President, Bonnie Merrill Limbach, Vice President of Public Affairs, and Jennifer S. Dills, Vice President of Corporate Communications

The Society of the Plastics Industry, Inc., 1801 K Street NW, Suite 600K, Washington, DC 20006, telephone: 202-974-5200, website: www.socplas.org

The Society of the Plastics Industry, Inc. is a trade association of over 2,000 members representing all segments of the plastics industry in the United States. SPI members include plastics processors, raw material suppliers, machinery manufacturers, mold makers and other industry-related groups and individuals. Founded in 1937, SPI serves as the voice of the plastics industry.

The mission of SPI is to promote the continued development of the plastics industry and enhance public understanding of plastics' contributions while meeting the needs of society. As the national trade association for the U.S. plastics industry, its strategy objectives are threefold:

- SPI represents and serves as the spokesperson for the industry locally, nationally, and internationally, with emphasis on influencing public policy on issues of concern to the industry.
- SPI works to ensure that plastics are a preferred material by actively demonstrating they are a responsible choice in an environmentally conscious world.
- SPI promotes industry growth, competitiveness, and the advancement of technology.

SPI accomplishes its objectives through a variety of programs designed to communicate the value of the plastics industry and its products to key audiences and to provide forums that enable the diverse interests within the industry to set policy and develop common goals and objectives. SPI represents the industry before federal and state government bodies, informs members about important legislative and regulatory policy developments, identifies trends and emerging issues of concern, and builds coalitions within the industry and with allied associations, customer groups, and other stakeholders to help achieve industry goals.

SPI also serves as a resource for members who need technical expertise, statistical information, and regulatory compliance assistance. It maintains liaisons with national and international technical and regulatory groups to develop standards for product performance and safety to protect existing markets for plastics and to open new ones.

Through its national, international, and regional activities, SPI promotes industry development through a variety of programs to improve company performance and create a positive business environment for the plastics industry.

SPI also sponsors two major trade shows—National Plastics Exposition (NPE) and Plastics USA—which provide a showcase for the industry and its products and an unparalleled forum for industry interaction. The triennial NPE attracts upward of 80,000 industry professionals from around the world to view the latest plastics innovations, products, technologies, and services. Plastics USA, also held every three years, serves as an industry update between NPEs, with a focus on the North American marketplace.

Complementing SPI's core services, SPI's business units and program committees serve the special needs of various industry segments. Some units are formed around specific materials, manufacturing processes, and end markets, while others represent plastics machinery and equipment manufacturers or product manufacturers.

In addition to its Washington, D.C., headquarters, SPI operates regional offices in the Boston, Chicago, and Los Angeles areas and in Greenville, South Carolina. SPI's regional offices and state chapters serve member needs on a more localized basis.

CHALLENGE 2000: MAKING PLASTICS A PREFERRED MATERIAL

Ronald H. Yocum, President and CEO, and Susan P. Moore, Vice President, Communications

American Plastics Council, 1300 Wilson Blvd., Suite 800, Arlington, VA 22209, telephone: 703-253-0700, website: www.plastics.org

When the American Plastics Council was formed just over six years ago, the U.S. plastics industry was still struggling with aftermath of the so-called garbage crisis of the late 1980s. We had been tagged as environmental bad guys—especially as the recycle-or-die mentality took root in the public consciousness. In the early 1990s, nearly half of all Americans—47 percent—thought the risks associated with using plastics outweighed the benefits. The plastics industry's favorability rating with the general population was down for around 52 percent favorable, while competing industries were in the low to middle 60 percent range.

Plastics are the most efficient, functional, and cost-effective choice for many applications. But there are few applications for which plastics are the only choice. Therefore, lagging far behind our competitors in the public's perception was a recipe for potential disaster, including the potential for the widespread deselecting of plastics. When faced with a risk-benefit equation that is unbalanced, you have two choices: you can drive up the benefits, or you can lessen the risk. Actually, there's a third choice: do both. That's what APC has worked to do.

Driving Up Benefits and Lessening the Risk

Our national ad campaign—Plastics Make It Possible®—is the most visible of these efforts. The ads are focused on driving up the benefits—especially benefits related to health and safety. We did a lot of research before making these ads because we wanted to know what kinds of messages would really affect public perceptions in a favorable direction. We found that our messages have to be personally relevant: they have to touch consumers' fundamental values. The ads display the messages that work the best.

Five years into the campaign, the plastics industries' favorability rating is now over 60, which is in the band with our competitors. In our most recent tracking polls, 98 percent of Americans agreed that plastics make important safety contributions in products such as tamper-resistant packaging, shatter-resistant bottles, bicycle helmets, and toys, to name a few. And 88 percent agreed that many products are safer because they are made with plastic as opposed to another material.

The U.S. plastics industry is making this progress in large part because our advertising helps people make more informed risk-benefit evaluations for themselves. What you don't see in the ads is a lot of environmental messages. That's because we've found the environmental benefits of plastics—source reduction, energy efficiency, combustion value—are difficult to communicate in a way that's personally relevant. Ads aren't the right vehicles for those messages.

Correcting Misperceptions About Plastics

There is also the issue of credibility. The lingering misperception that we are a solid-waste bad guy undercuts our ability to communicate as an industry about the environment. But as individuals we can communicate credibly and effectively on a wide range of issues—including the environment.

Our industry is in a good position as we near the new millennium, but in many ways our industry and our products are still misunderstood. Let's take on this challenging opportunity to correct the public's misperceptions of plastics. For instance, although recycling is now firmly entrenched as a societal goal, the solid-waste issue in general seems to have lost its urgency in recent years. Polls used to show that air and water pollution were dominant environmental concerns, but that trend may be changing. In a recent poll, nearly seven in ten people said they believe that serious disposal or environmental problems are associated with the use of plastics. This increase of 13 points over 1996 indicates that waste concerns are the primary source of negative perceptions of plastics.

Part of our job is educating the public that plastics recycling is working and working well. In the United States, an independent, entrepreneurial industry has evolved to use postconsumer resin (PCR) in ways that maximize its value. For instance, the industry is relatively stable and established with more than 52,000 Americans now employed in the plastics recycling business. In fact, at last count more than 1,700 businesses were engaged in either handling or reclaiming postconsumer plastics. The PCR they produce today goes into making more than 1,400 products such as bottles, clothing, timbers for landscaping and decking, carpets, and stadium seating. And APC is actively involved in working with the industry to both research and promote recycling with a variety of audiences.

Nevertheless, we're seeing more state-level legislation pushing extended manufacturers' responsibility. These proposals would require manufacturers to fund and operate redemption centers for a wide variety of packaging. Proponents of these bills argue that they will increase the amount of material recovered for recycling, but as the European experience has shown, this simply is not the case. Draconian measures such as Germany's Green Dot program increase the regulatory and economic burden on manufacturers, but their impact on recycling rates is negligible. We're also keeping a close eye on issues such as global climate change and allegations about the potential health effects of plastics additives. If any of these issues comes to the forefront, we need to be prepared as an industry to mobilize and take advantage of the relationships we're building today to communicate our messages.

The Need for Worldwide Plastics Advocates

Being an advocate for plastics isn't a part-time role, and it isn't something one becomes once every two years when there's a summit. It's an everyday thing. Every one of us has countless opportunities to be a spokesperson for plastics. Just think of all the different places you interact with the people of your community—the grocery store, a town meeting, your local school. We all need to be enthusiastic volunteers to present the benefits of plastics to local associations, clubs, voters, and any other service group that will grant us use of their podium.

But above all else, keep in mind that being an advocate for plastics does not mean knowing all the answers. No one in our industry can safely claim to be an expert on every issue affecting plastics. For this reason, we all need to learn how to comfortably say: "You know, I don't think you're right about that. Let me look into that and get back to you."

APC is ready and willing to help the plastics industry worldwide become effective advocates, and we encourage you to visit our website at www.plastics.org and utilize our communications arsenal. Just about every piece of information APC has is available through our website. Please take advantage of it in your daily activism while encouraging others to visit. It's an easy way to refer people to a comprehensive source of facts on a wealth of subjects. APC is a resource and a partner in helping our industry to shape a future that creates a marketplace valuing plastics for their performance, versatility, and environmental profile.

ADVANCING THE PLASTICS INDUSTRY THROUGH EDUCATION AND RESEARCH

Aldo Crugnola, Ph.D., Executive Director, Nick R. Schott, Ph.D., Director for Educational and Research Programs, and A. G. (Manny) Panos, Associate Director

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The Plastics Institute of America is a not-for-profit organization whose members come from industry, academia, and government. Its primary objective is to help advance the growth and progress of the plastics industry through education and research. Corporate members of the PIA include large and small producers of plastics products, commodity and engineering resins, additives for plastics, plastics packaging, and process machinery, as well as educators, international industry associations, government agencies, and trade publications. Major organizations that have representation on PIA's board of directors include the Society of Plastics Industry, the Society of Plastics Engineers, the Society of Manufacturing Engineers, the Plastics Pioneers Association, and the National Plastics Center.

The Early Years

The Institute was organized in 1961 by SPE because the Society's board of directors felt the organization was placing too much emphasis on sales and too little on science and technology. New polymers were being introduced at that time, and the industry lacked qualified personnel to work with these materials. PIA took steps to remedy this problem by awarding fellowships to graduate schools that offered programs and conducted research in polymer science. The few educational institutions addressing these issues in those years included Princeton University, Brooklyn Polytechnic Institute, Lowell Technological Institute, and Stevens Institute of Technology. PIA made its headquarters at the Stevens's campus in Hoboken, New Jersey. The organization soon began offering graduate fellowships and conducting short courses aimed at updating education industry personnel and university faculty members. By working in concert with colleges and universities, PIA was able to conduct courses featuring lecturers from both industry and the academic world. The organization later expanded this effort to include three-day conferences on the "hot" industry issues of the day such as benchmarking, time-dependent effects, packaging technology, and recycling. In 1990, PIA left Stevens and established a new headquarters in Fairfield, New Jersey. Six years later, the Institute moved once again, this time to the Lowell, MA, campus of the University of Massachusetts. The PIA offices now reside there in the same building as the Institute for Plastics Innovation, a technology center for plastics manufacturing. Coincident with that move, the Institute named Dr. Aldo Crugnola of UMass Lowell as its new executive director.

PIA Today

The PIA today continues to offer a diverse array of educational programs for all segments of the industry from in-plant training for workers on the shop floor to industry-specific short courses and seminars for executives. In-house programs are tailored to enhance the skill levels of machine operators, plant mechanics, electronic technicians, and other support personnel. Executive courses concentrate on administrative issues, including new technologies, concurrent engineering, work organization, and legal issues. The Institute also conducts international conferences on emerging issues such as Recyclingplas, Foodplas, and Constructionplas. These events bring together representatives from industry, government, and academia. In addition, the PIA responds to a variety of industry needs not addressed by other organizations. These initiatives include:

- Research Fellowships which are awarded to graduate students pursuing research in Plastics engineering and polymer science and Plastics Pioneers Association Technology Scholarships which go to students preparing for a career in plastics.
- Publication of a Directory of Plastics Education & Training (formerly Polymer Science & Engineering) Programs—a guide listing two- and four-year college programs, vocational school programs, short courses, video training, and computer-based self-study programs offered by commercial institutes.
- Industry surveys to determine research needs. (Emphasis on industrial to research contact)
- An informal resource and "hot line," providing knowledge/advice on plastics materials/processing.

In all of its initiatives, PIA seeks to complement—not compete with—other nationally known plastics associations and societies.

MODERN PLASTICS IN THE YEAR 2000

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Modern Plastics and *Modern Plastics International*

Modern Plastics and *Modern Plastics International*, the undisputed leaders in plastics trade publishing globally (77,000 qualified subscribers and approximately 338,000 pass-along readers), are doing even more to help the plastics industry in 2000. We plan to again invest $2.1 million in qualifying and expanding our global circulation. This will guarantee our coverage of the plastic suppliers, processors, and end users that account for 80 percent and more of business and capital expenditures. This is part of the mandate we have fulfilled since 1924—that of providing superior editorial and premier circulation to give the best return for reading and advertising investments.

The New *Modern Plastics World Encyclopedia* in the Year 2000

Our redesigned book features major changes and additions. The *Modern Plastics World Encyclopedia* now contains a chapter on each primary process and articles on the latest industry trends and developments. Each chapter contains machinery charts in U.S. and metric standards as well as a comprehensive global Buyers' Guide by process, including sales and service offices and sales agents.

Resins and chemical charts are changed to accommodate ISO standards. New charts will include blowing agents, impact modifiers, and chemical resistance. Specific alloys will be added to the resin section of the classified product listing. A reformatted company index easily guides you to listings in the Buyers' Guide by page number and section.

Modern Mold and Tooling

Modern Mold and Tooling will be published 10 times in 2000, with a North American and an international version. This will enable us to better serve the moldmaking industry and provide a focused readership of moldmakers, molders, and industrial end-users who own, specify, and purchase molds.

The *Modern Mold and Tooling* trade show, which is the largest and most successful event for the moldmaking industry in the Americas, will become bigger and better. The exposition and conference takes place yearly in Chicago's McCormick Place, the premier exhibition site in America.

The *Plastics Platform*

The Internet-based *Plastics Platform*, which went online in mid-1998, is another example of a unique product we are investing in, one connecting suppliers of raw materials with plastics processors. Included in the basic package are

- Online resin offers and inquiries from the first polymer market.
- Spot pricing, price trends, and real-time news from Standard & Poor's Platt's.
- Background articles, trends, analyses by material type, and a global Buyers' Guide of raw material suppliers from *Modern Plastics* and *Modern Plastics International.*

Plastics Handbook

The *Plastics Handbook* provides a fundamental overview of all major process types and related primary machinery, auxiliary and secondary equipment, materials, and additives.

Resins Pocket Guide

The *Resins Pocket Guide* is a global information source for plastics resins, additives, reinforcements, and fillers. It includes information on suppliers, products, trade names, and sales offices. Suppliers from over fifty countries are listed with address, telephone, toll-free telephone, fax, telex, e-mail, and web information provided. Supplier representatives in 146 countries are also included with address, telephone, and fax information. The product listings include information on resins, compounds, additives, reinforcements, and fillers for 189 product categories. Each item under a product category includes supplier name, country, and trade name.

The trade name listing includes all trade names for plastics resins, additives, reinforcements, and fillers. Each trade name is followed by a product description, supplier name, and supplier's country.

- In the *location index*, suppliers are listed by country and by operation type (primary producer, compounder, distributor, and broker).
- In the *operation index*, suppliers are listed by operation type (primary producer, compounder, distributor, and broker).
- In the *country*, *representative*, and *supplier index*, countries, representatives in these countries, and all the suppliers associated with each representative are listed.

PLASTICS TECHNOLOGY IN THE NEW MILLENNIUM

Matthew H. Naitove, Editor, and James J. Callari, Publisher

Plastics Technology, 355 Park Avenue South, New York, NY 10010-1789, telephone: 212-592-6580, website: www.plasticstechnology.com

The first issue of *Plastics Technology* appeared in February 1955. By 1961, *Plastics Technology* had become the first magazine devoted entirely to the interests of plastics processors, and that has remained its focus ever since. *Plastics Technology* magazine reports on technical innovations and interprets manufacturing trends for fabricators of any kind of plastics product. Each month, managers of plastics-processing operations in the United States and Canada get early word of new materials, equipment, and techniques for keeping up with competitors around the world. They also get analysis of how new business challenges will affect their operations.

We report on all areas of plastics processing for every kind of application—from toys to electronics and disposable packaging to automobile and appliance parts. We provide practical problem-solving assistance as well as buyers' guides to new or little-known categories of machinery, raw materials, software, or services. We also provide monthly summaries of business and market news, updates on resin prices, analysis of regulatory developments that will affect our readers, and quarterly surveys of readers' capacity utilization and machine-hour pricing rates.

We serve over 47,000 subscribers (and about 94,000 pass-along readers) with positions in production, general corporate management, R&D, quality control, and tool design. Most readers share an engineering background and hands-on manufacturing experience.

In addition to the monthly magazine, *Plastics Technology* publishes an annual *Manufacturing Handbook and Buyers, Guide*, which contains technical specifications on and product-line descriptions of plastics machinery, materials, and additives supplied in North America. A directory of products and suppliers is also included. Our processor service focus also extends to our unique online *PLASPEC* Databank and Plastic Technology *AUXILIARIES*, a bimonthly new product tabloid. The *PLASPEC* Databank of Materials and Equipment Specifications, plus a *Supplier Directory*, is featured on our website (www.plasticstechnology.com), which also offers a daily news column and searchable archives of *Plastics Technology* articles since 1993.

The annual *Processing Handbook and Buyers' Guide* is included as part of an annual subscription to *Plastics Technology* magazine (Table 1).

Table 1. Content Headings of *The Processing Handbook and Buyers' Guide.*

Conversion Chart (English to metric units and vice versa)	Auxiliary and Secondary Equipment
Primary Machinery	Materials Handling Equipment
Injection Molding	Robots and Other Parts Handling Equipment
Blow Molding	Decorating, Printing, Finishing Systems
Extrusion Systems	Welding and Assembly Equipment
Pelletizers and Dicers	Chemicals and Additives
Thermoforming	Blowing Agents
Structural Foam	Catalyst and Curing Agents
Rotational Molding	Colorants (Pigments, Dyes, Concentrates, Pastes)
Compression/Transfer	Fillers
RIM Machines	Flame Retardants
Urethane Processing	Impact Modifiers
Reinforced Plastics	Lubricants and Processing Aids
Compounding, Mixing, Blending	Mold-Release Agents
Tooling	Plasticizers
Injection Molds	Stabilizers
Blow Molds	Antioxidants
Hot-Runner Components and Systems	PVC Heat Stabilizers
Heaters and Heating Elements	UV Stabilizers
Temperature Sensors, Monitors, Controls	Thermoplastic Materials
Pressure Sensors, Monitors, Controls	Thermoset Materials
Liquid Temperature-Control Equipment (Chillers, Mold-Temperature Controllers, Cooling Towers)	Classified Directory of Suppliers (Primary Equipment, Auxiliary Equipment, Materials, Chemicals and Additives, Specialized Services)
Granulators and Pulverizers	Alphabetical Directory of Suppliers
Recycling Systems	

Note: Many sections are accompanied by suppliers' data sheets.

PLASTICS NEWS: BORN TO FEED NEED FOR NEWS

Robert C. Grace, Editor/Associate Publisher, and Anthony J. Eagan, Vice President/Publisher

Plastics News, 1725 Merriam Road, Akron, OH 44313-5251, telephone: 330-836-2322, website: www.plasticsnews.com

Plastic News: The Newspaper

The seed that became *Plastics News* was planted in fall 1988, when the board of Crain Communications Inc. approved the launch of North America's first weekly plastics newspaper. The objective was to create a high-frequency, independent, news-driven publication to serve the thousands of North American plastics-processing companies whose actions seldom merited scrutiny anywhere but in their local community newspapers. *PN*'s mission is to provide independent, multisourced, timely coverage and analysis of plastics companies, markets, trade associations, people, events, and legislation.

Plastics News was to differ sharply not only in frequency and format but also in substance and style from anything the plastics market had seen before. *Plastics News*' hard-hitting, controversial editorial columns put everyone on notice that *PN* would not follow in the trade press's supplier-friendly pattern of never treading on toes, and *PN*'s weekly chart tracking U.S. market resin prices—as opposed to list prices—also prompted controversy (and fury) among resin suppliers.

Those early days were exhausting but exhilarating to *PN* staff, as the paper's daily-style journalism provoked strong reactions. Competitors maligned *PN* since it ran controversial stories that they wouldn't dare touch—but the publication touched a chord with readers. Today, among U.S. plastics publications, *Plastics News* has risen from ninth to first place in total annual revenues. More than half its 60,000 readers have general and corporate management titles, the highest such percentage in the industry.

Plastics News, in each weekly issue, covers the industry's latest and most significant business, economic, pricing, legislative, environmental, technological, and end-market developments. It produces six annual, dollar-based rankings of North American plastics processors, with separate surveys of injection molders; thermoformers; rotational molders; film and sheet manufacturers; pipe, profile, and tube extruders; and blow molders. These rankings currently cover more than 1,800 companies and include sales figures, markets served, number of plants, materials processed, and more. *PN* also ranks plastics recyclers and industry executives' salaries. Its annual, year-end *Market Data Book* summarizes in print form the previous year's complete processors rankings and includes further data on key global industry trade associations, North American compounders, resin pricing trends, and the coming year's important conference/exhibit events.

Plastics News—with an editorial staff of sixteen plus several news correspondents around the world—is distributed throughout North America and has licensing arrangements with publishers in China and Brazil that allow those firms to translate and redistribute some of *PN*'s editorial content in those major markets.

Other key *Plastics News* features include several online offerings.

Plastics News on the Web

Launched in April 1996, *PN*'s content rich website (www.plasticsnews.com) serves as a global daily industry news wire, often posting and updating stories several times each day before they hit the streets in the following Monday's print edition. The site offers much free data to all visitors and also includes a paid-subscriber zone that offers access to more than 12,000 searchable, full-text stories from *PN*'s archives (dating back to January 1994) and historical resin pricing data (in many cases dating to 1989). Website visitors can register to have breaking-news headlines "pushed" to them daily, for free, via e-mail.

Supplier Search

An online interactive, global search tool is designed to help product manufacturers, designers, and specifiers find and qualify exactly the right supplier. Internet users worldwide can search the *Supplier Search* centralized database for free. Technically detailed templates and a powerful search engine allow users to identify and communicate with firms that meet their specific parameters in terms of process type, capabilities, and location. Several sections also include links to Dun & Bradstreet reports on the companies.

Web Watch Directory

The *Web Watch* directory, an online search engine of plastics industry-relevant websites, allows users to select from approximately sixty descriptions of companies or organizations (such as associations, blow molders, extrusion machinery suppliers, compounders, consultants, and so on). When searching for a certain type of processor, users can filter further by choosing the type of end market served (such as injection molders and medical). The search-results pages provide links directly to the sites that match your search parameters. Inclusion in and use of the *Web Watch* directory is free.

MOLDING OUR FUTURE VISION

Suzy Witzler, Editor, T. Peter Sullivan, Publisher and CEO, and Peter M. Zacher, Vice President, Sales

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The Magazine

Injection Molding Magazine, founded in 1993, is written for the injection-molding marketplace and reaches 37,000 people throughout North America who are involved in all aspects of creating and manufacturing injection-molded products. Its interdisciplinary approach seeks to create better communication among all those who touch the development of an injection-molded product.

- *Product design* *IMM* reaches OEM design departments and independent design engineering firms throughout North America where molded products start. Here initial design concepts are developed, products are engineered, and processes and materials are specified. *IMM* reaches the people who perform this critical function, where many important decisions are made that affect sales.
- *Mold design and moldmaking* *IMM* reaches moldmakers, where product development is further refined, and moldmaking departments inside custom and captive molding operations, where mold maintenance and repair occurs. Without the expertise of the moldmaker, products cannot be produced.
- *Molding operations* *IMM* reaches the molding operations themselves—both custom and captive—where products are manufactured, finished or decorated, assembled, and sold. Executive and management functions; sales and marketing departments; production managers, engineers, and technicians; and quality control people work together to bring molded products to market.
- *Technical support* *IMM* also reaches people who perform the important technical functions at companies that supply their products and services to injection molders. These include the R&D, technical service, design, and manufacturing professionals who influence the purchase not only of their own products but of the many other products that molders buy. Their technical guidance helps molders run effective operations.

IMM's editorial mission is to provide in-depth coverage of the issues that affect all job responsibilities in this marketplace—management, sales and marketing, design, tooling, and manufacturing professionals. In addition to the monthly magazine, a number of other resources are available through the publication's professional relationship with the injection molding community.

IMM Book Club

The *IMM* Book Club offers the world's largest collection of books, software, videos, CD/ROMs, and training programs related to molding—all selected exclusively for injection molders. *IMM* Book Club selections have been chosen with the input of *IMM* reviewers, who are seasoned injection-molding professionals. Members receive the *IMM Book Club News*, a quarterly newsletter containing insightful book reviews by the *IMM* reviewers, new book and sales announcements, and news about special events. The Book Club's website (www.immbook-club.com) offers online ordering, access to reviews of all products, and an online forum. Those seeking resources may ask the *IMM* Book Club librarian for help.

IMM Online

The magazine's website (www.immnet.com) is also a comprehensive source of technical and business information. Key areas of the site include the following:

- *Editorial Library* An archive of three years of *Injection Molding Magazine* offers full-text articles with graphics, plus a searchable database indexing all editorial material in the magazine's history. A *New Product Showcase* lists hundreds of recently introduced products related to injection molding. Economic forecasts for the molding industry are posted monthly.
- *Networking Forum* This moderated forum is used to network with injection-molding professionals from around the world. *Search Threads* allow searching for discussions on a specific subject; the search form will retrieve a list of relevant posts. *Begin Thread* allows generation of a new discussion by starting a unique thread of interested parties.
- *Tricks of the Trade* This troubleshooting archive offers problems and solutions to common molding problems.
- *Calendar* An events-related calendar lists conferences, expositions, technical meetings, seminars, and workshops.

Other Resources

The IMM Almanac

This searchable database lists hundreds of products used in injection molding operations and those who supply them, including contact information, web and e-mail addresses; and product line descriptions. A series of *Purchasing Basics* articles and a list of resin distribution companies complete the package, which is available online at www.immnet.com or in print form.

- *Directory of Manufacturers Representatives* The *Directory* is a comprehensive book and database listing those who call on injection-molding operations and the products they represent.
- *Business books* *IMM* also publishes books relating to the business side of injection molding, specifically *The Business of Custom Injection Molding* and the *Molding Strategies* series of management, marketing, and sales texts.
- *IMM conferences and seminars* *IMM*-sponsored management conferences, technical seminars, and workshops are dedicated to injection-molding professionals.
- *Other Products* *IMM* also offers targeted mailing lists, reprints, postcard decks, customized research, and merchandising programs.

Stated Simply

IMM is comprehensively focused on the injection-molding professional, with an eye to molding an interactive and personalized future vision for the molding community.

THINKING LIKE A MANAGER AND MANAGING FOR THE LONG RUN

Leonard A. Schlesinger

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Effective management is much more than the production of immediate results. Effective management includes creating the potential for achieving good results over the long run. The manager who as president of a company produces spectacular results for a three- to ten-year period can hardly be considered effective if, concurrently, he or she allows plant and equipment to deteriorate, creates an alienated or militant workforce, lets the company develop a bad name in the marketplace, and ignores new product development.

Dealing with current or impending problems is a key reality of managerial behavior in almost all modern organizations. Coping with complexities associated with today and the immediate future absorbs the vast majority of time and energy for most managers. This review sets the stage for placing management in a longer time frame. How do managers develop their organizations to ensure the potential for facilitating organizational effectiveness in the long run?

The Long Run

Most managers will readily admit that their ability to predict their company's future is limited. Indeed, with the possible exceptions of death and taxes, the only thing entirely predictable is that things will change. Even for the most bureaucratic company in the most mature and stable environment, change is inevitable.

Over a period of twenty years, it is possible for a company, even one that is not growing, to experience numerous changes in its business, product markets, competition, government regulations, available technologies, labor markets—and its own business strategy. These changes are the inevitable products of its interaction with a world that is not static.

Growing organizations tend to experience even more business-related changes over a long period of time. Studies have shown that growing businesses not only increase the volume of the products or services they provide but also tend to increase the complexity of their products or services, their forward or backward integration, their rate of product innovation, the geographic scope of their operations, the number and character of their distribution channels, and the number and diversity of their customer groups. While all of this growth-driven change is occurring, competitive and other external pressures also increase. The more rapid the growth, the more extensive the changes that are experienced.

These types of business changes generally require organizational adjustments. For example, if a company's labor markets change over time, it must alter its selection criteria and make other adjustments to fit the new type of employee. New competitors might emerge with new products, thus requiring renewed product-development efforts and a new organizational design to support that effort. In a growing company, business changes tend to require major shifts periodically in all aspects of its organization (see Tables 1 and 2).

The inability of an organization to anticipate the need for change and to adjust effectively to changes in its business or in its organization causes problems. These problems sometimes take the form of poor collaboration and coordination; they may involve high turnover or low morale. Always, however, such problems affect the organization's performance: goals are not achieved or resources are wasted.

Because change is inevitable and because it can so easily produce problems for companies, the key characteristic of an effective organization from a long-run viewpoint is its ability to anticipate needed organizational changes and to

Table 1. Greiner's Summary of Required Changes in Organization Practices During Evolution in the Five Phases of Growth.

Category	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Management focus	Make and sell	Efficiency of operations	Expansion of market	Consolidation of organization	Problem solving and innovation
Organization structure	Informal	Centralized and functional	Decentralized and geographic	Line staff and product groups	Matrix of teams
Top management style	Individualistic and entrepreneurial	Directive	Delegative	Watchdog	Participative
Control system	Market results	Standards and cost centers	Reports and profit centers	Plans and investment centers	Mutual goal setting
Management reward emphasis	Ownership	Salary and merit increases	Individual bonus	Profit sharing and stock options	Team bonus

Source: Larry E. Greiner (1972), "Evolution and Revolution as Organizations Grow," *Harvard Business Review* (July-August), 45.

Table 2. Summary of Changes During Three Stages of Organizational Development.

Company Characteristics	Stage I	Stage II	Stage III
The Business			
Product	Single product or single line	Single product line	Multiple product lines
Distribution	One channel or set of channels	One set of channels	Multiple channels
R&D	Not institutionalized—oriented by owner-manager	Increasingly institutionalized search for product or process developments	Institutionalized search for *new* products as well as for improvements
Strategic choices	Needs of owner versus needs of firm	Degree of integration; market-share objective; breadth of product line	Entry and exit from industries; allocation of resources by industry rate of growth
The Organization			
Organization structure	Little or no formal structure—one-man show	Specialization based on function	Specialization based on product or market relationship
Product or service transactions	Not available	Integrated pattern of transactions: A → B → C → Market	Not integrated: ABC ↓ ↓ ↓ Market
Performance measurement	By personal contact and subjective criteria	Increasingly impersonal using technical and/or cost criteria	Increasingly impersonal using market criteria (return on investment and market share)
Rewards	Unsystematic and often paternalistic	Increasingly systematic with emphasis on stability end service	Increasingly systematic with variability minted to performance
Control system	Personal control of both strategic and operating decisions	Personal control of strategic decisions, with increasing delegation of operating decisions based on control by policies	Delegation of product or market decisions within existing businesses with indirect control based on analysis of results

Source: Adapted from Bruce Scott (1971), *Stages of Corporate Development* (Boston: HBS Case Services).

adapt as business conditions change. Anticipatory skills can help prevent the resource drain caused by organizational problems, while adaptability helps an organization avoid the problems that change can produce. Over long periods of time, this ability to avoid an important and recurring resource drain can mark the difference between success and failure for an organization.

A Case of Organizational Decline

To fully appreciate the importance of anticipatory skills and adaptability in the long run, consider this somewhat extreme case. This company was founded in the late 1920s, primarily through acquisitions. It was created as the response of an entrepreneur to a variety of changing market conditions. Over a five- to ten-year period, he established an enormously successful venture. In its market, it became the largest and most profitable organization of its kind.

Historical records do not reveal how much, if anything, the entrepreneur did to develop the company's long-run organizational adaptability. Two facts, however, are known. First, the ongoing operations were so profitable that he submitted to the demands of the national union just to avoid a disruption of operations. This resulted in the establishment of innumerable work rules and the entry of first-line supervisors into the union. Second, he did almost nothing to bring in or develop mid- or top-level managers. As an extremely talented person capable of making a large number of effective business decisions himself, he saw no need for assistance from others.

In the mid-1940s, the entrepreneur died. His brother took over as president and tried to maintain the company's existing policies and profitability. For the first few years of his tenure, everything seemed to work well.

After World War II, the company's industry, like many others, began to undergo significant changes. These changes occurred gradually but continuously over at least a ten-year period. During this time the company made very few organizational adjustments to adapt to these changes, for a number of reasons. First, the few people who had any real decision-making authority in the company did not seem to see a need for many changes. They simply did not have the information that would have shown them what was happening in their industry and in their market area. Second, when they did have information on the changes that were occurring, they had difficulty deciding how to adjust to them. They were, for example, completely unaware of the typical development sequences shown in Tables 1 and 2. The intuitively brilliant leadership supplied by the original entrepreneur was gone, and nothing had taken its place. Finally, when they did identify a change and saw what response was needed, the managers were generally unable to implement it. For one thing, union rules prohibited a great deal of change; for another, there was no middle management to help them implement it. The firm was not at all flexible.

Some of the company's competitors were successful in identifying and reacting to the industry and market changes. As a result, the rate of increase of this company's sales and profits began to decrease. At the same time, problems with employees and the union began to surface.

The company's president initially focused his efforts on trying to stop the profit decline. In this endeavor, he was somewhat successful, yet in slowing the profit decline, he was forced to hold salaries and maintenance budgets down, thereby adding to the problems with his employees and the union. A climate of antagonism and distrust developed.

Between 1956 and 1965, the company's real (noninflated) annual growth in sales declined from 5 to 0 percent. Its profits leveled out and then fell to a net loss in 1965. By that time, the company's stock price was so low that a larger corporation successfully acquired a controlling interest. This corporation brought in its own top management group (which included a number of extremely successful managers) and predicted a quick turnaround.

The company resumed profitable operations in 1969 and, with the exception of 1973, has remained profitable to this time. Nevertheless, its profitability levels remain below the industry average, and its 1975 sales were, in real dollars, about the same as in 1965. It has gone through two more presidents since 1965, and the current one has been quoted in the business press as saying that the job of organizational "renewal" that is ahead of them remains extensive.

Characteristics of an Effective Organization from a Long-Run Point of View

It is possible to infer the characteristics that contribute to long-run effectiveness by looking for what was missing in the previous example. The picture that emerges is one of an organization where (1) changes in its business are anticipated or quickly identified, (2) appropriate responses are quickly designed, and (3) the responses are implemented at a minimum cost. This behavior would be possible because the company is staffed with talented managers who are skilled at organizational analyses as well as having relatively adaptable employees. Trust, open communications, and respect for others' opinions would characterize informal relations among these people. The formal design would include effective integrating devices, sensitive and well-designed measurement systems, reward systems that encourage adaptability, and selection and development systems that help support all other characteristics (see Table 3).

Table 3. Characteristics of a Highly Effective Organization: A Long-Run Point of View.

Employees
- The company is staffed with more than enough managerial talent.
- Managers are skilled at organizational analysis and understand typical stages of organizational development.
- A large number of employees are relatively adaptive and have skills beyond a narrow specialty.
- Employees have realistic expectations about what they will get from, and have to give to, the company in the foreseeable future.

Informal Relations
- A high level of trust exists between employees and management.
- Information flows freely, with a minimum of distortion within and across groups.
- People in all positions of responsibility are willing to listen to, and be influenced by, others who might have relevant information.

Formal Design
- The organizational structure includes more than enough effective integrating mechanisms for the current situation and relies minimally on rules and procedures.
- Measurement systems thoroughly collect and distribute all relevant data on the organization's environment, its actions, its performance, and changes in any of these factors.
- Reward systems encourage people to identify needed changes and help implement them.
- Selection and development systems are designed to create highly skilled managerial and employee groups and to encourage the kinds of informal relations described above.

Unlike the declining company described earlier, an organization with the characteristics listed in Table 3, as well as other characteristics that specifically fit its current business, could successfully respond to growth, industry changes, top management turnover, and virtually anything else that came its way. Its adaptability would allow it to continue changing the organization to fit its changing business, and it would survive and even prosper over long periods of time.

Bureaucratic Dry Rot

Very few companies or nonprofit businesses have organizations with characteristics even close to those described in Table 3. This fact has been emphasized by a number of social scientists who, in the past decade, have expressed serious concern over what they call *bureaucratic dry rot.* We all pay a heavy price, they note, for the large, bureaucratic, nonadaptive organizations that are insensitive to employees' needs, ignore consumers' desires, and refuse to accept their social responsibilities.

Existing evidence suggests that although most contemporary organizations cannot be described as adaptive, many managers nevertheless appreciate the benefits of adaptability. When polled, managers often respond that ideally they would like to have the kind of organization suggested by Table 3, but they also admit that their current organization does not have all or even some of these characteristics.

At least five reasons account for the inflexibility and shortsightedness of most contemporary organizations. The first and most significant relates to resources. Creating a highly adaptive organization requires time, energy, and money. In the case of the company that went into decline, creating an adaptive organization early in its history might have required

- Hiring, assimilating, and training a management team, both at the top and in midlevel ranks,
- Selecting and training all other personnel,
- Concentrating efforts from the managers to develop integrative devices, measurement systems, and the like, and
- Developing and maintaining good, informal relationships among managers and their employees.

The organization may not have had the resources to invest in these systems. Had it tried, the company might have been compelled to divert resources from some of its current operations. If its competitors did not choose to follow its lead but continued to invest as heavily as possible in current operations, perhaps the company would have lost market share and income and even gone out of business long before it could enjoy the benefits of its long-term investment in adaptability.

A second reason for the nonadaptive and bureaucratic behavior of modern organizations is that their managers are not very skilled at producing the characteristics of an effective organization in the long run. Organizations generally invest resources in current operations and not in producing adaptive human systems. The on-the-job education of managers is usually focused on current operations, not on producing adaptability. Generating the characteristics shown in Table 3 requires skills that have to be developed and nurtured.

Still a third reason for the inflexibility of many contemporary organizations is that some people clearly benefit from a static situation. The entrepreneur who established the nonadaptive organization described earlier thoroughly enjoyed the way he ran the company. It is doubtful that he would have invested resources in developing a management team or developed one even had it cost him nothing. Furthermore, financial backers approved of how he ran the business, which included passing on a large share of the firm's earnings in dividends. Had he tried to cut the dividends to invest more in something as intangible as adaptability, they undoubtedly would have protested.

A fourth reason for nonadaptive behavior also is evident in the case of decline. Once an organization reaches a certain size, if it has not developed a certain minimally adaptive human organization, it becomes very difficult to turn things around without a gigantic infusion of resources. Considerable effort is required simply to overcome the organizational entropy that makes the organization even more nonadaptive and rigid.

A fifth reason more companies do not have organizational characteristics like those in Table 3 is their management's decision that such characteristics are unnecessary. Based on their projection of what the future has in store for their company, management estimates how much adaptability they will need and then invests resources to produce only that level of adaptability. If the company is growing very quickly or if it is in a volatile market and management expects rapid changes to continue in their business, it would invest considerable resources in creating an adaptive human organization. However, if the company is not growing, if it is in a stable market, and if management feels the future will not demand many changes of them, it generally invests relatively few resources.

In short, the forces that prevent organizations from developing a high level of adaptability are strong. The forces that can push successful organizations into decline are numerous as well. As a result, one of the most difficult of all management tasks involves developing an organization that has enough adaptability to promote effectiveness in the long run.

Six Tasks of the Manager Who Manages for the Long Run

If a manager's goal is to create a lasting, high-performance company, focusing on the six key tasks that constitute the basics of the manager's job in any company is one way to achieve that elusive goal. These six basic tasks include (1) building a positive work environment, (2) establishing strategic direction, (3) allocating and marshalling resources, (4) upgrading the quality of management, (5) organizing effort, and (6) creating excellence in operations and execution.

Nothing should be surprising about this list; the fundamentals of the job should sound familiar. The vast majority of the activities that managers perform in any situation can be grouped into these headings. The tasks help a manager define the scope of the job, set priorities, and see important interrelationships among the six areas.

Task 1: Building a Positive Work Environment

Every company has a particular work environment that dictates to a considerable degree how its managers respond to problems and opportunities. A company's work environment—whether a small company, medium-sized one, or a giant like General Motors or General Electric—is partly a heritage of its past leaders. Shaping that environment is a critically important part of every incumbent manager's job, regardless of what he or she inherits from the past. Over time, most managers exert influence on their work environment by three types of actions: (1) establishing goals and performance standards, (2) establishing values for the organization, and (3) establishing business and people concepts that are consistent with their goals and values.

The basic goals of the company provide a unifying force for channeling efforts in chosen directions and elevating performance standards. Individually, they provide direction in selected areas. Collectively, they influence the way people act in a company. Specific, action-oriented goals describe an aggressive and demanding work environment and influence the way people respond to strategic opportunities and business problems within the company. Conversely, a company with no specific goals or vague or undemanding ones is much more likely to drift, be bureaucratic, or tolerate unexciting results.

Successful managers typically set high standards across the whole business. High standards are reflected in many ways, including (1) the relative quality of the company's functional strategies and its market leadership; (2) the detailed end results that are sought and achieved, as compared to relevant competitors; (3) the quality of written plans and oral presentations that people make, both in terms of substance and style; (4) the relative quality of managers at all levels; (5) rising productivity in all functions of the business, particularly as compared with major competitors; and (6) consistent product quality and reliability.

Values reflect the relative concern that an organization has for its employees, customers, investors, suppliers, and other stakeholders. Values help define not only the manner in which business will be conducted (how these stakeholders will be treated) but the types of business in which an organization will engage. The fit between an individual and an organization is often determined by these values.

An organization's values are reflected in its business concepts, for example, (1) the kinds of products or services the business will offer, (2) the company's position or role in its industry, and (3) structural devices, such as levels of organization, methods of communication, and planning processes to be employed in conducting business. Policies that support such values include (1) internal growth from operations; (2) hiring from within; (3) fairness in performance assessment and rewards; (4) fairness in dealing with people; and (5) candor, integrity, and high ethical standards in relationships.

In any organization, the manager's personal style influences associates for better or worse. If the manager insists on long memos or frequent meetings, these usually will be the order of the day throughout the organization. A hands-on style will be widely copied. The cost-conscious manager results in cost consciousness throughout much of the organization. If the manager favors complex systems, this too will usually have a ripple effect throughout the company. Other managers take their cues from the manner in which their manager responds to others' successes or failures.

The manager's style influences the ethical tone of the business. The manager's actions tell associates far more than words. A manager who lacks integrity, fairness, or a sense of commitment quickly creates confusion and cynicism in the organization. Conversely, managers who set high standards in these areas usually find their associates following their lead. The importance of consistency between what general managers say and how they act in creating a sound working environment hardly can be overstated.

Managers can be most effective if they have an all-encompassing theme for the working environment. The theme can be converting a slow-moving company into a dynamic business, becoming an industry's innovative merchandising leader, or becoming a blue-chip company. Successful leaders frequently use such broad themes to help focus the working environment on one overriding purpose.

Task 2: Establishing Strategic Direction

Whether the manager is the main architect of the company's strategy, he or she is responsible for ensuring that a process is in place for strategic planning. There is no universally accepted definition of what constitutes a good strategy. Some companies make elaborate efforts to spell out what they mean by a strategy; in others, the strategy consists largely of ideas contained in the manager's head. In any case, the manager is the executive who must decide whether the business will be run on the basis of an explicit, formalized strategy and, if so, the process to be employed in developing, reviewing, and implementing it.

A commonly accepted framework for strategy formulation and appraisal highlights the following elements: (1) the task, including the environment and concept of the business, its definition, mission, competitive position, and functional goals and efforts; (2) available resources, including leadership, human capital, financial assets, technological assets, customer franchises, stakeholder relationships, and working environment; and (3) structure, including organization, controls, systems, standards, rewards, policies, processes, and values.

A starting point in the process of strategy formulation and appraisal is an understanding of the task facing the business. Devices such as Michael Porter's "five forces analysis" can be useful here. Just as important is an understanding on the part of the manager of the way a business runs and the important factors in its success or failure. An *operational* understanding of the business is critical.

Managers typically face several issues in organizing people's efforts to develop and review strategy, including making decisions about (1) those who will be directly involved and the role that they will play; (2) the format of the plans; (3) the mechanisms needed to gain the input, understanding, and commitment of key managers as plans evolve; (4) the nature of the review and approval process; and (5) the manager's individual role in the process.

During the process of strategy formulation and review, the manager is faced with a sequence of important decisions that determine the effectiveness of the strategy. Successful strategies usually start with good ideas and evolve over time as they are exposed to the realities of the marketplace.

The scarce resource in strategy development often is bold, innovative ideas—those that provide a new vision for the business rather than a slight alteration of existing strategy. Hence, managers must stimulate everyone, including themselves, to think creatively and to be willing to consider fresh approaches. This is true whether the manager does most of the thinking personally or serves more as the prime mover for the process.

Task 3: Allocating and Marshalling Resources

Successful strategies require resources to convert them into reality (including both hard resources [like cash, plant and equipment, and offices] and soft resources such as people and technology). The manager's unique role in resource allocation stems from three distinctive features of the job. First, the manager is the only person who can commit resources across the entire business. Since nearly every major strategy entails cross-functional commitments, the manager is normally the only executive empowered to make these commitments.

Second, the manager must be the chief decision maker about tradeoffs among key projects and functions competing for limited resources. Since most businesses lack the resources to do everything that is proposed, this is usually a major responsibility.

Third, once a decision is made to pursue a strategy, the manager assumes the responsibility for marshalling the resources needed to ensure success.

Marshalling resources often involves the manager in a series of negotiations with external entities (such as financial institutions, major investors, government agencies, and labor unions) as well as internal constituents.

While strategy decisions have an important influence on resource allocations, managers, of course, also routinely allocate resources to operate the business. It is important for a manager to be sure that both kinds of resources—strategic and operational—are productively employed.

Task 4: Upgrading the Quality of Management

Many managers contend that the selection, development, and deployment of people are the most important responsibilities. They also feel it is a satisfying part of the job to see managers grow and the organization strengthen as a result of their efforts. Managers who attach a high priority to this activity usually find their associates do also.

In addition, most skillful managers personally involve themselves in (1) defining and supervising the process for selecting and developing the company's senior and upper-middle management (such as stressing individual evaluations and development assignments), (2) seeing that each function periodically analyzes its skill requirements and people needs and has a strategy to fill those needs, (3) setting job requirement standards (at least at top levels), (4) making sure that outstanding managers have challenging, timely development assignments that effectively utilize their talents, (5) ensuring that compensation programs are both competitive and rewarding for managers who meet assigned goals, and (6) making sure that entry-level management jobs are sufficiently challenging to attract the best people.

Task 5: Organizing Effort

Because of their cross-functional responsibilities, managers normally play a dominant role in designing the company's organization. This function usually includes three important activities:

1. *Defining the organizational concepts for the company* This means deciding (in light of the company's competitive and general environment) the appropriate level in the organization at which important business decisions should be made, how tightly or loosely controlled the business will be operated, and the role that measurements, controls, and policies play in running the business.
2. *Deciding on the organization structure at the top* Important questions to be addressed here include, What is expected of each key functional area? Where does it report? What subunits will it contain? How will each function work together? What are the necessary line and staff relationships? What role will the general manager play?
3. *Defining interfunctional relationships* In most organizations, the manager is the only executive who can be held responsible for coordinating major functional relationships. Moreover, how the manager defines and supervises these important relationships usually determines how smoothly functional groups work together.

Organizations are naturally dynamic, they change with shifts in competitive conditions, strategic thrust, or the talent available to the general manager. Therefore, the processes of organization design, staffing, and coordination are nearly always an ongoing, high-priority concern of the manager.

Task 6: Creating Excellence in Operations and Execution

Typically, the manager influences day-to-day operations in three major ways: (1) by his or her style, (2) by the management processes used (consistent with that style), and (3) by the way time is allocated. If the manager is a direct, personal leader, things will usually be done in a direct, personal way. Less direct leaders may rely on a consensus-driven approach. Whatever the style, the manager is responsible for understanding day-to-day operations and for establishing the processes that govern them. The manager will typically be involved in (1) operational planning including the development of annual plans and efforts to see that they are met; (2) coordination among the direct-report functions, with special concern that functional units work together so that proper tradeoffs are made, parochial departmental interests do not dominate, and inevitable interfunctional conflicts are resolved; (3) decision making, with primary emphasis on cross-functional matters and major commitments; and (4) problem identification and solution, whether through direct involvement or setting in motion a process for the purpose.

The manager's responsibilities cover a wide range of activities. Individually, they may not be as important or as interesting as the development of a business strategy. Taken together, however, they keep the business going effectively, meeting its short-term sales and profit goals. Without an understanding of day-to-day operations, a manager will have difficulty identifying important elements of the strategic task facing the firm.

Concluding Comments

These six basic tasks of the manager represent an arbitrary selection. However, they do represent discrete and broad responsibilities important to the successful performance of the manager's job in most companies.

A primary skill of the manager is to pick the specific areas where his or her involvement will have the greatest impact on business results. The scope of the job is such that a manager nearly always faces many more problems and opportunities than he or she can possibly deal with personally. The manager may decide to put greater emphasis on strategy formulation; at another time, the focus will be on the development of people or the working environment. Knowing what to emphasize, when to emphasize it, what and when to delegate, and to whom to delegate are crucial decisions.

Success as a manager isn't solely a function of focusing on these key tasks. Some managers are simply better leaders than others. Some bring a personal package of experience or style that is especially suited to a particular situation.

However, whatever leadership skills or personal package a manager brings to the job, he or she still must decide specifically how to focus efforts in order to fundamentally improve the business. Therefore, the key tasks come into play in nearly every situation.

A skillful manager usually is the most important contributor to an organization's success over time. Those contributions are most effective when efforts are concentrated in the six areas described above.

For Further Reading

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MAKING MARKETING WORK

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"Marketing is the distinguishing, the unique function of the business. Any organization in which marketing is either absent or incidental is not a business and should never be run as if it were one." This quotation, from Peter F. Drucker's book *The Practice of Management* (which was written more than forty years ago) is even more appropriate today, in the global economy of the 2000s. Yet everyone, it seems, questions both the need and the validity of marketing.

First, we should define the term. Marketing is the series of functions that help explain what one has to sell. Today, a company markets itself through advertisements, press releases, corporate literature, trade shows, mailings, papers and seminars, research, and more recently, a website on the Internet. All these, and more, are marketing.

Corporate staff frequently questions the validity of marketing. Production asks why some of the best products are eliminated from production while less efficient models go right on selling, why a predictable relationship is not established between price and cost, and why some of the very best test products are abandoned. Financial personnel ask why there is such a great expenditure on promotion and distribution, why there are so many identical products, and why independent distribution systems are not used. Even headquarters have queries, such as why the company uses outside firms and consultants, why so many marketing decisions are made quickly, and why one magazine was selected over another for ad placement.

Because marketing and management must work as a team, it is mandatory that both recognize and understand the various questions and points of view. To a marketer—even a successful one—such issues as shortest possible delivery times and high-quality products relate to a loss or gain in sales. The marketer is at the mercy of a faulty production schedule, insufficient funding, or records that are inadequate to help identify potential markets or customers. Marketing needs production, finance, and even headquarters. And they all must work together.

There is a myriad of other factors that work against marketing, and many of these are outside the company. Rather than first looking at what makes marketing work, one can begin by looking at the ten key reasons why marketing fails and why marketing is perceived as unable to achieve the desired results:

1. Marketing may not be sending the correct message to the correct audience. A good example is the case of Mercedes in past years: the messages about its new cars were coming from the engineers, and new developments based on customer demand were not forthcoming. As Mercedes raised prices and told customers what they should want on their cars, the more consumer-oriented BMW took away a substantial market share. During a trade show, one can see the selling of features rather than benefits, and thus the wrong message, by going from exhibit booth to exhibit booth.
2. Marketing fails when it does not match the budget to the goals. Sponsors of Indy 500 cars have a saying that "Speed costs money," which applies to marketing as well. A consumer-product success such as the Elmo craze during the 1996 Christmas season would not have done nearly so well if the product had not been promoted on the *Rosie O'Donnell Show*. Of course, both luck and timing were factors, but if the firm had not spent the money to have the toy placed on the show by high-priced professionals, perhaps Elmo would not have achieved such popularity.
3. Marketing efforts fail if they do not make a significant impact. One can criticize the "Ring Around the Collar" ads and say "Who cares?" to the latest beer commercials, but in fact they do make impressions and do sell washing machine detergent and beer.
4. A failure to use correct techniques is a certain way to fail at marketing. The advertising of a product on an appropriate television show, as discussed above, is an example of using a correct method. Examples abound, however, of companies that did not adequately plan a marketing campaign and then concluded that advertising does not work.
5. Marketing fails if it is not persistent. Studies have shown that it takes a typical salesperson at least four to six contacts to close a sale. Yet these same studies have shown that most salespeople quit or become discouraged after the second call or contact. Marketing efforts must be sustained.
6. Marketing fails if it does not grab attention. Attention-getters include the EverReady bunny, the Alka Seltzer ads of yore, and the BMW Z3 sports car giveaway by HPM Corporation at the 1997 NPE. With regard to HPM's efforts, 30,000 people entered the contest, and it is likely that most of them passed through the HPM booth.
7. Marketing fails dismally when it does not understand the customer. Extensive research and common sense are the keys to success here. The marketing staff must learn what the customer wants, not what they think the customer wants or what they want the customer to hear.
8. Marketing may fail if it does not use cutting-edge methods. To prove this point, one can look at firms that are successfully using the Internet to sell. At one

time, most people were content to purchase one computer; today, people seem to be buying new computers almost annually, convinced by computer manufacturers that they must have the new machines to stay current.

9. Marketing fails if it is not based on adequate research. Basic research before and after a marketing plan is vital, as evidenced by the Chrysler Corporation's success with its Neon automobile. It is possible that General Motors' Saturn is suffering because the cars are not viewed as cutting edge or as what consumers want and need. Now, Chrysler is toying with a new concept car that ironically looks strangely similar to the old Citroen. But companies must also engage in ongoing research, as Volvo did, finding that consumers wanted changes in the relatively new 850 series of autos. Volvo quickly responded with the newer and improved S70 and V70 series.
10. And last, marketing will fail if one does not recognize results. Goals should be set at the outset and the means of measuring results agreed on. More important, changes should be made as required to make sure intended outcomes can be achieved.

Another approach to the issue of marketing practices is to discuss how to recognize—and thus avoid—the seven pitfalls that one may encounter in marketing. It is true that unforeseen events happen, which can force a company to take a closer look at its marketing: competition increases or becomes stronger, a new player enters the fray, market conditions change, or sales simply drop. But in general, marketing is most effective if staff in the production, financial, or even corporate sectors learns to recognize these seven misconceptions or strategic errors:

1. The belief that price is the driving force in increasing sales. It has been shown that customers fail to perceive any value in doing business with a firm that consistently offers deep discounts, makes special concessions, or engages in deals. That type of firm is viewed as a vendor, not a partner.
2. Lack of differentiation of a company's product or service from that of a competitor. The value-added qualities of one's offerings must be evident.
3. The presentation of sales gimmicks. When nothing is really special, customers know it.
4. The constant changing of sales strategies.
5. The assumption that most sales leads come from the sales force. An ad, a trade show, or a magazine article can reach thousands of potential customers in the time it takes a salesperson to reach a few. Furthermore, many of these leads would not have been uncovered in any other way.
6. Lack of cross-selling to current customers or lack of trying to resell products to them. If a company cannot complete new sales with established customers, it is difficult to expect success with those who are only prospects.
7. An inadequate or nonexistent customer and prospect database. In most selling situations, a couple of years are needed for a purchaser to narrow down the list of suppliers and close the sale, during which time the potential customer may not remember a particular company's name. Thus, databases should be utilized to contact the customer or the prospective customer on a continuing basis.

It is important to consider what is actually required to gain a 1 percent share of the market. One can envision a situation in which a marketing manager has 100,000 prospects while the current sales staff can take on no new customers. The manager might add ten new people to the sales staff. If they were 100 percent efficient, they could see 1,000 prospects each month. Since studies have shown that sometimes four, but usually as many as six, calls are needed to close an average industrial sale, at least four months—and a million dollars—would be required to persuade 1 percent of the company's prospects to buy a product from the firm. And this is without considering other factors that might influence a potential customer's decision, such as the opinions of purchasing or manufacturing personnel or of top management.

In conclusion, the marketplace in which we all strive to sell and grow is both fast-paced and customer-dominated, making stronger marketing more important than ever before. Our business system operates on the assumption that people, and thus companies, do their very best when they know that good performance will benefit them directly. As an example, if a company discovers that a competitor has a new product on the market with a price similar to that of an earlier product but of superior quality, the former company should respond to the challenge by making its own products or services

Marketing must be persistent, it can be measured, and it does have a positive effect on any company's sales and growth. Long ago, a top marketing person at General Motors made a claim that is still very viable today. He said, "I've discovered that 50 percent of my marketing really, truly works; I've also come to the conclusion that the other 50 percent doesn't work very well. The problem is, I don't know which 50 percent works, and which doesn't. But I can only imagine how disastrous things might be if we didn't market as aggressively as we do." Thus, one can say that the more people that a company contacts, the more likely a company can increase its sales.

THE PLASTICS INDUSTRY: ALL SECTORS, INCLUDING MACHINERY AND EQUIPMENT

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The plastics industry is characterized by a wide variety of distinct processing methods or techniques that fabricate many different plastic materials into many different products. Figures 1 and 2 provide a summary of the interrelations of plastics, processing, and products. This practical sequence of events shows how products are fabricated to meet the performance and cost requirements that are used substantially in all industries. This back-to-basic approach summarizes the logical sequence in manufacturing goods from the initial design concept to the customer receiving the end use product.

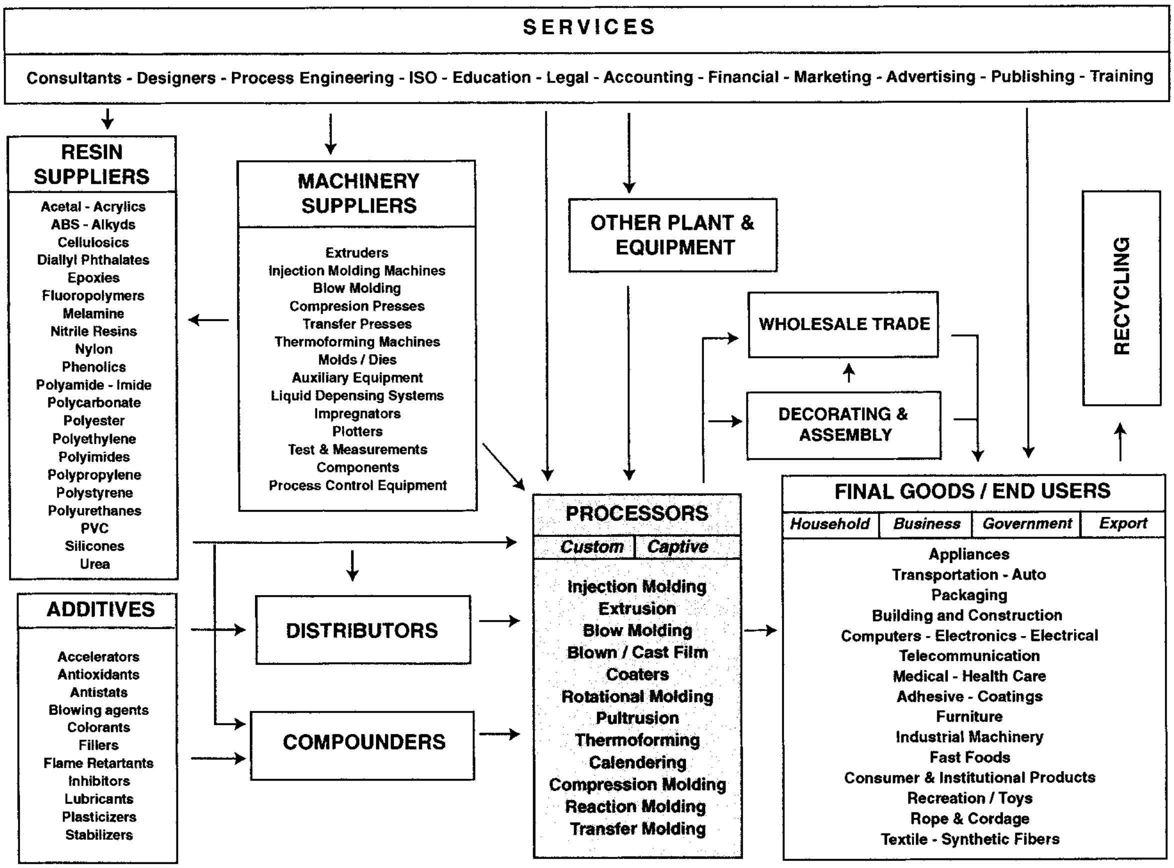

Fig. 1. The Plastics Industry.

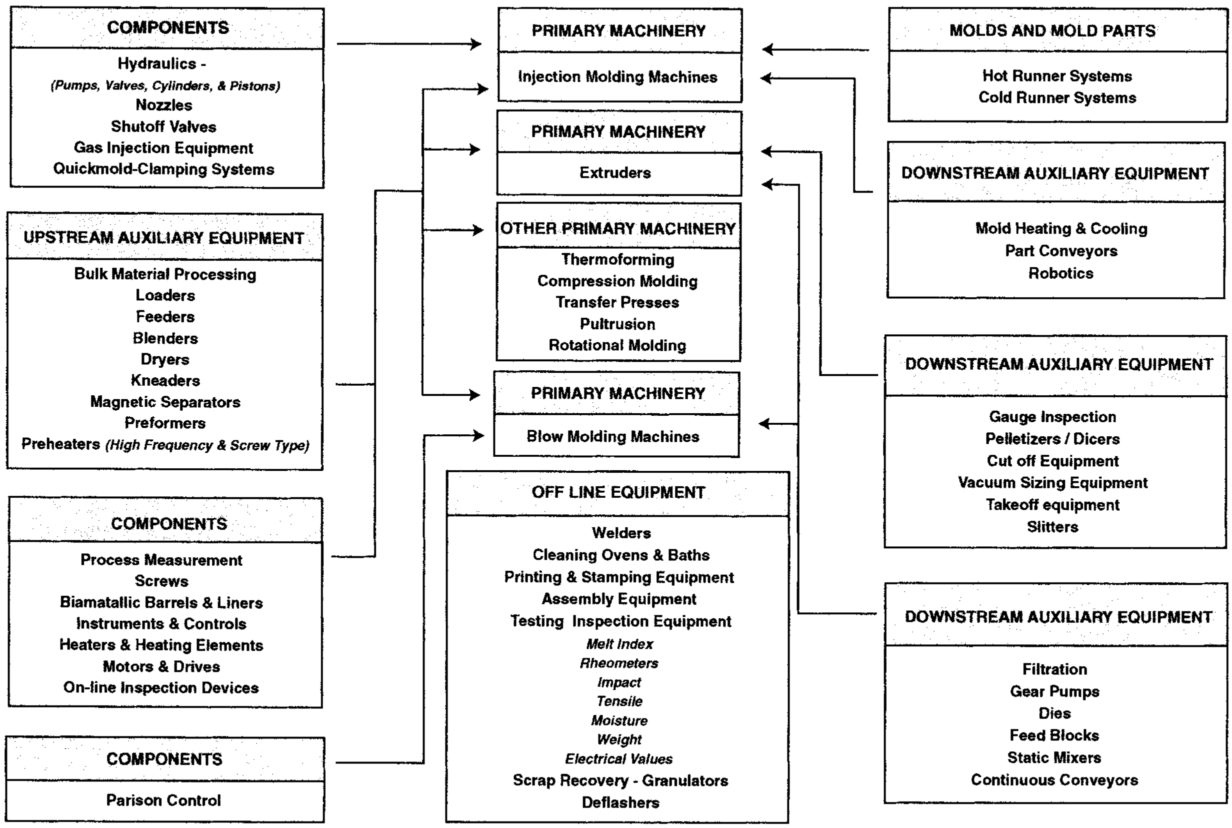

Fig. 2. The Plastics Machinery and Equipment Sector.

BASICS AND OVERVIEWS OF PLASTICS FABRICATING PROCESSES

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The worldwide effect of plastics on people and industries is due to the intelligent application of modern chemistry and engineering principles. Plastics utilize the versatility and vast array of inherent plastic properties as well as high-speed, low-energy processing techniques to develop cost-effective products that are used worldwide.

Figures 1 to 7 and Tables 1 to 6 provide an introduction to the many factors that are important to making plastics. All processes fit into an overall scheme that requires interaction and proper control of different operations, such as using the FALLO Approach (Follow ALL Opportunities).

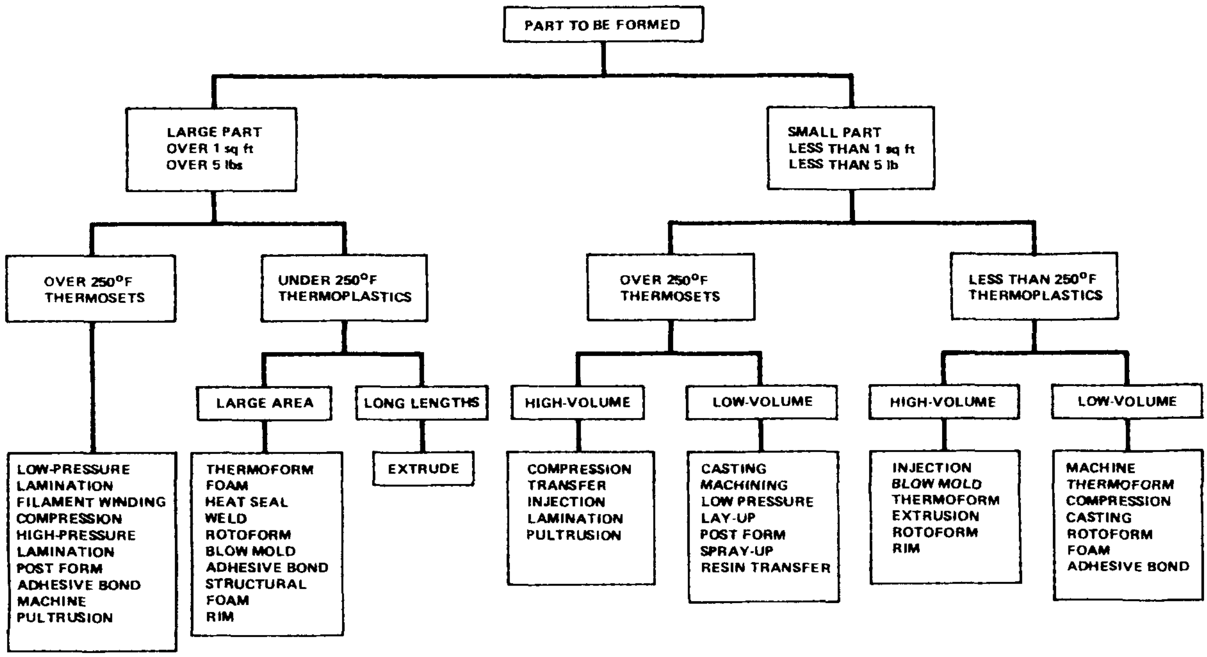

Fig. 1. Guide to Process Performances. (All figures in this article are taken from the source: DVR, Injection Molding Division Newsletter, Society of Plastics Engineers.)

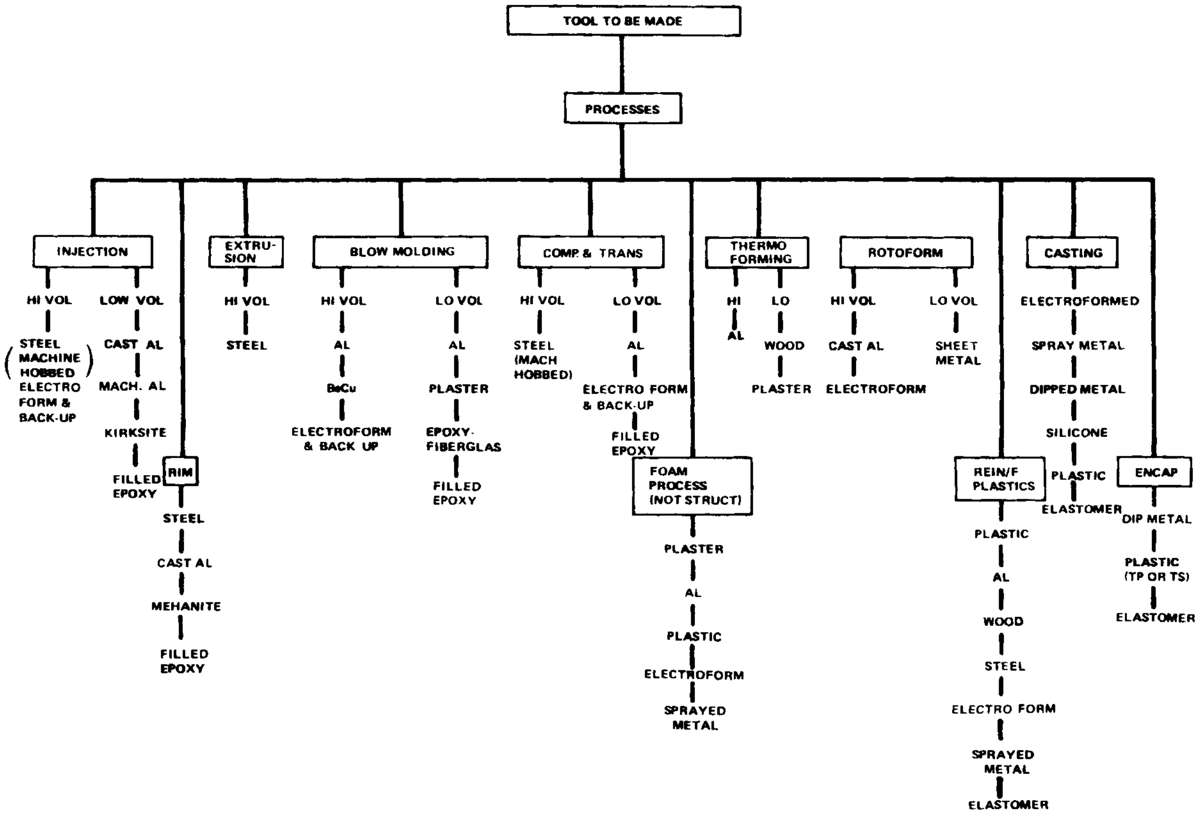

Fig. 2. Guide to Tools.

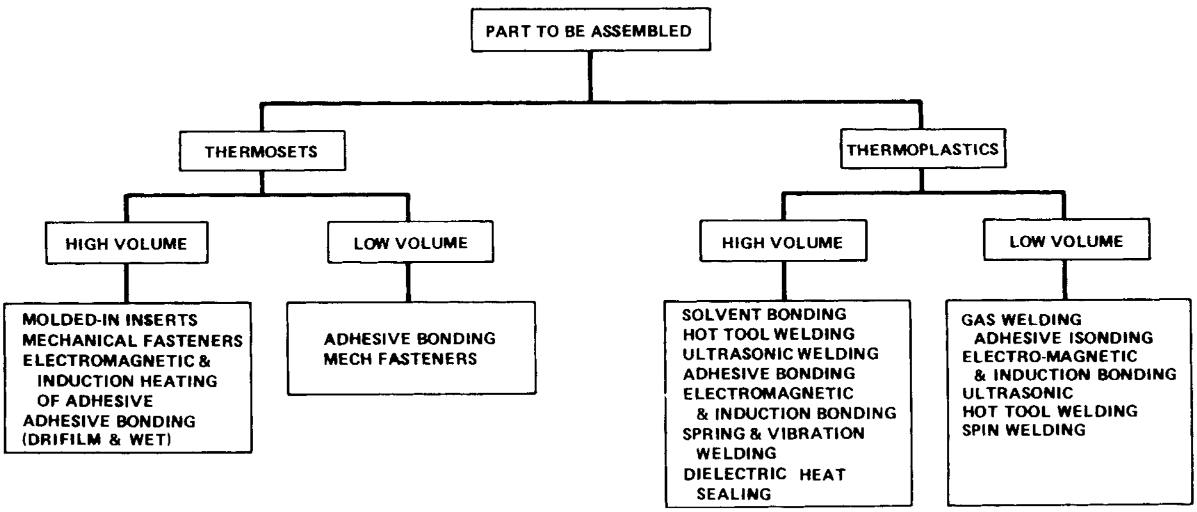

Fig. 3. Guide of Part to Be Assembled.

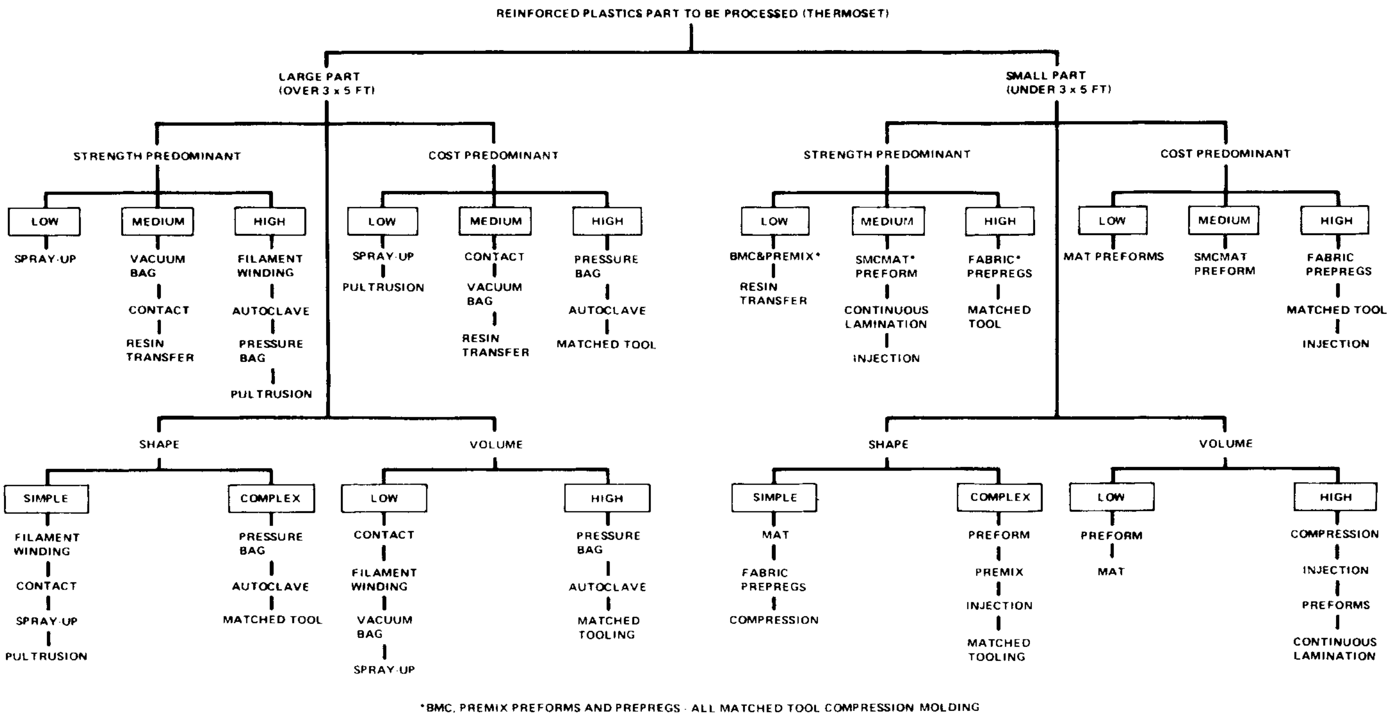

Fig. 4. Guide to Reinforced Plastics Part to Be Processed (Thermoset).

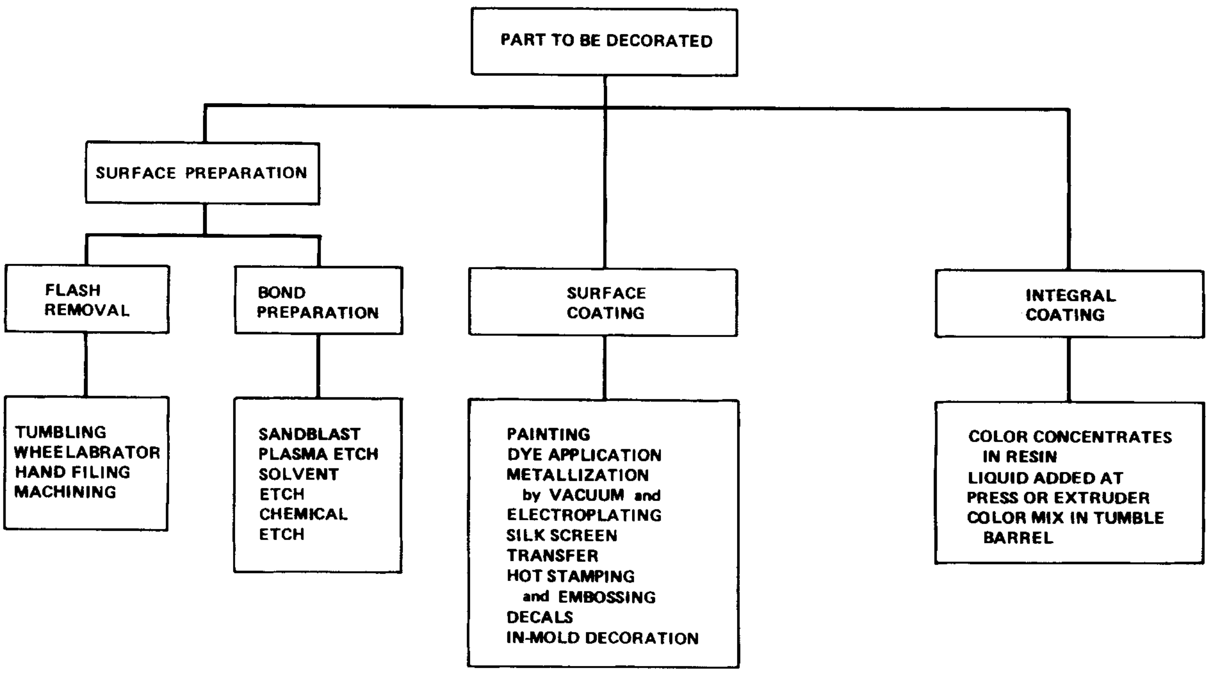

Fig. 5. Processing Guide to Part Decoration.

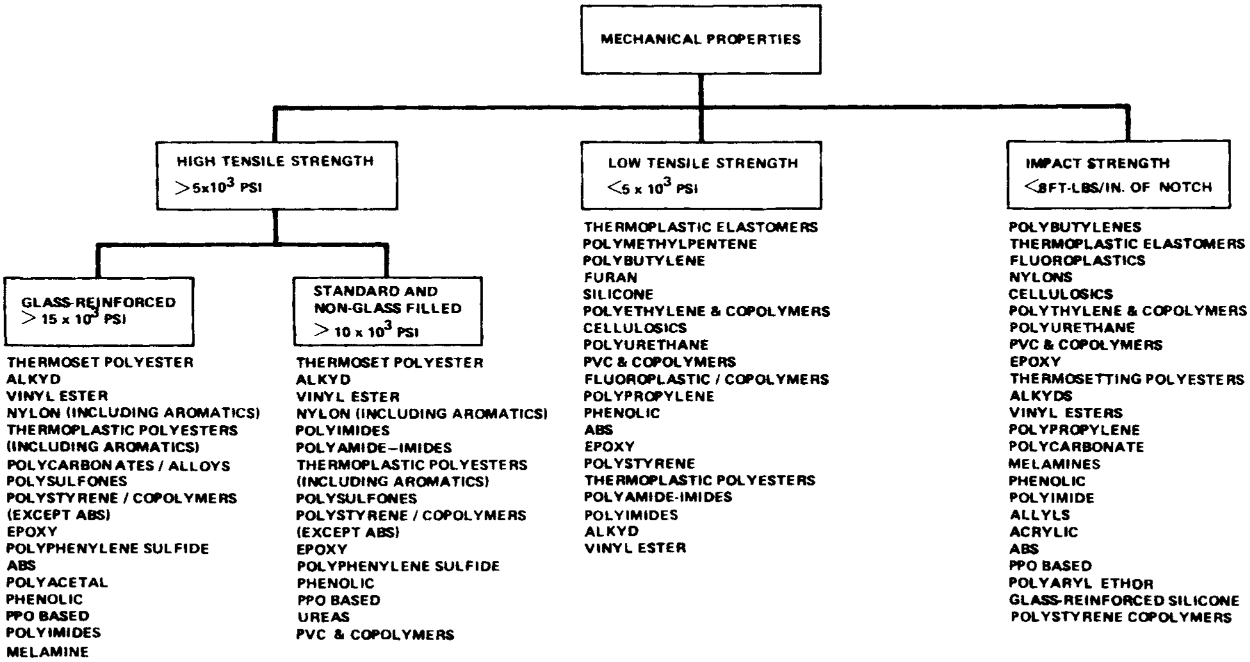

Fig. 6. Guide to Mechanical Properties.

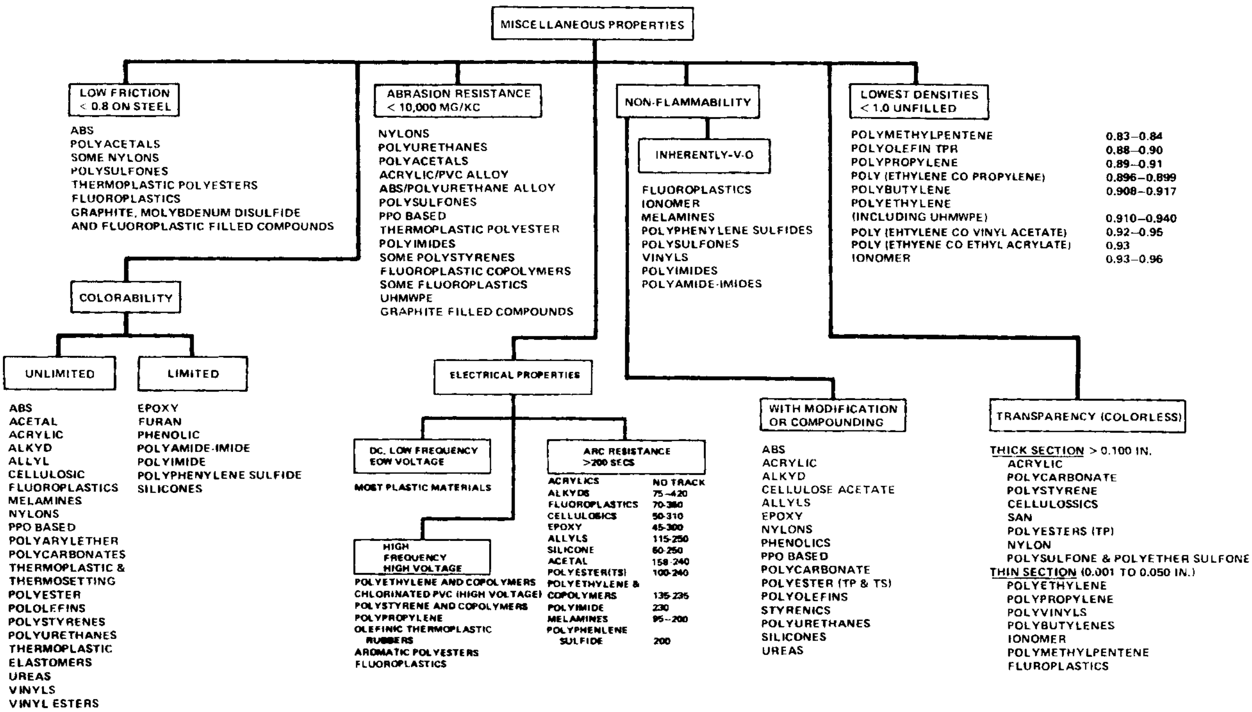

Fig. 7. Guide to Other Properties.

Table 1. Guide to Processing Different Plastics. (All tables in this article are taken from the source: DVR, Injection Molding Division Newsletter, Society of Plastics Engineers.)

Material Family	Injection	Compression	Transfer	Casting	Cold Molding	Coating	Structural Foam	Extrusion	Laminating	Sheet Forming	RP Molding FRP	Filament	Dip and Slush	Blow	Rotational
ABS	X						X	X		X				X	
Acetal	X						X	X		X				X	X
Acrylic	X			X		X		X	X	X				X	
Allyl		X	X	X	X	X			X			X			
ASA	X						X	X		X					
Cellulosic	X					X	X	X	X	X				X	X
Epoxy		X	X	X	X	X			X			X			
Fluoroplastic	X	X	X		X	X		X		X					X
Melamine-formaldehyde	X	X	X	X		X			X						
Nylon	X			X		X	X	X						X	X
Phenol-formaldehyde	X	X	X	X	X	X			X						
Poly (amide-imide)	X	X	X					X							
Polyarylether	X							X							
Polybutadiene	X		X					X						X	
Polycarbonate	X	X					X	X		X				X	X
Polyester (TP)	X					X		X						X	X
Polyester-fiberglass (TS)		X	X					X	X		X	X			X
Polyethylene	X	X				X	X	X	X	X				X	X
Polyimide	X	X				X		X(TP)							
Polyphenylene oxide	X						X	X							X
Polyphenylene sulfide	X	X				X									
Polypropylene	X						X	X		X				X	X
Polystyrene	X						X	X		X				X	X
Polysulfone	X	X						X		X					
Polyurethane (TS) (TP)	X	X	X	X		X	X	X(TP)	X	X				X	X
SAN	X						X	X	X	X					X
Silicone		X		X				X							
Styrene-butadiene	X					X		X	X						
Urea-formaldehyde		X							X						
Vinyl	X	X				X	X	X	X	X			X	X	X

[a]Compounding permits using other processes.

Table 2. Guide to Compatibility of Processes and Material.

	Thermosets					Thermoplastics										
	Polyester	*Polyester SMC*	*Polyester BMC*	*Epoxy*	*Polyurethane*	*Acetal*	*Nylon-6*	*Nylon-6,6*	*Polycarbonate*	*Polypropylene*	*Polyphenylene sulfide*	*ABS*	*Polyphenylene oxide*	*Polystyrene*	*Polyester PBT*	*Polyester PET*
Injection molding	X		X	X	X	X	X	X	X	X	X	X	X	X	X	
Hand layup	X			X												
Sprayup	X			X												
Compression molding	X	X	X	X							X					
Preform molding	X			X												
Filament winding	X			X												
Pultrusion	X			X												
Resin transfer molding	X													X	X	X
Reinforced reaction injection molding	X			X	X		X									

Table 3. General Information Relating Processes and Materials to Plastic Properties.

Thermosets	Properties	Processes
Polyesters Properties shown also apply to some polyesters formulated for thermoplastic processing by injection molding	Simplest, most versatile, economical and most widely used family of resins, having good electrical properties, good chemical resistance, especially to acids	Compression molding Filament winding Hand layup Mat molding Pressure bag molding Continuous pultrusion Injection molding Sprayup Centrifugal casting Cold molding Comoform Encapsulation
Epoxies	Excellent mechanical properties, dimensional stability, chemical resistance (especially alkalis), low water absorption, self-extinguishing (when halogenated), low shrinkage, good abrasion resistance, very good adhesion properties	Compression molding Filament winding Hand layup Continuous pultrusion Encapsulation Centrifugal casting
Phenolics	Good acid resistance, good electrical properties (except arc resistance), high heat resistance	Compression molding Continuous laminating
Silicones	Highest heat resistance, low water absorption, excellent dielectric properties, high arc resistance	Compression molding Injection molding Encapsulation
Melamines	Good heat resistance, high impact strength	Compression molding
Diallyl phthalate	Good electrical insulation, low water absorption	Compression molding
Thermoplastics		
Polystyrene	Low cost, moderate heat distortion, good dimensional stability, good stiffness, impact strength	Injection molding Continuous laminating
Nylon	High heat distortion, low water absorption, low elongation, good impact strength, good tensile and flexural strength	Injection molding Blow molding Rotational molding
Polycarbonate	Self-extinguishing, high dielectric strength, high mechanical properties	Injection molding

Table 3. Continued.

Thermoplastics	Properties	Processes
Styrene-acrylonitrile	Good solvent resistance, good long-term strength, good appearance	Injection molding
Acrylics	Good gloss, weather resistance, optical clarity, and color; excellent electrical properties	Injection molding Vacuum forming Compression molding Continuous laminating
Vinyls	Excellent weatherability, superior electrical properties, excellent moisture and chemical resistance, self-extinguishing	Injection molding Continuous laminating Rotational molding
Acetals	Very high tensile strength and stiffness, exceptional dimensional stability, high chemical and abrasion resistance, no known room temperature solvent	Injection molding
Polyethylene	Good toughness, light weight, low cost, good flexibility, good chemical resistance; can be 'welded'	Injection molding Rotational molding Blow molding
Fluorocarbons	Very high heat and chemical resistance, nonburning, lowest coefficient of friction, high dimensional stability	Injection molding Encapsulation Continuous pultrusion
Polyphenylene oxide, modified	Very tough engineering plastic, superior dimensional stability, low moisture absorption, excellent chemical resistance	Injection molding
Polypropylene	Excellent resistance to stress or flex cracking, very light weight, hard, scratch-resistant surface, can be electroplated; good chemical and heat resistance; exceptional impact strength; good optical qualities	Injection molding Continuous laminating Rotational molding
Polysulfone	Good transparency, high mechanical properties, heat resistance, electrical properties at high temperatures; can be electroplated	Injection molding

Table 4. Basic Processing Methods as a Function of Part Design.

Part Design	Blow Molding	Casting	Compression	Extrusion	Filament Winding	Injection	Matched Die Molding	Rotational	Thermo-forming	Transfer Compression	Wet Layup (Contact Molding)
Major shape characteristics	Hollow bodies	Simple configurations	Moldable in one plane	Constant cross section profile	Structure with surfaces of revolution	Few limitations	Moldable in one plane	Hollow bodies	Moldable in one plane	Simple configurations	Moldable in one plane
Limiting size factor	Material	Material	Equipment	Material	Equipment	Equipment	Equipment	Material	Material	Equipment	Mold size
Maximum thickness. in. (mm)	>0.25 (6.4)	None	0.5 (12.7)	6 (150)	3 (76)	6 (150)	2 (51)	0.5 (12.7)	3 (76)	6 (150)	0.5 (12.7)
Minimum inside radius. in. (mm)	0.125 (3.18)	0.01–0.125 (0.25–3.18)	0.125 (3.18)	0.01–0.125 (0.25–3.18)	0.125 (3.18)	0.01–0.125 (0.25–3.18)	0.06 (1.5)	0.01–0.125 (0.25–3.18)	0.125 (3.18)	0.01–0.125 (0.25–3.18)	0.25 (6.4)
Minimum draft (deg.)	0	0–1	>1	NR[b]	2–3	<1	1	1	1	1	0
Minimum thickness. in. (mm)	0.01 (0.25)	0.01–0.125 (0.25–3.18)	0.01–0.125 (0.25–3.18)	0.001 (0.02)	0.015 (0.38)	0.005 (0.1)	0.03 (0.8)	0.02 (0.5)	0.002 (0.05)	0.01–0.125 (0.25–3.18)	0.06 (1.5)
Threads	Yes	Yes	Yes	No	No	Yes	No	Yes	No	Yes	No
Undercuts	Yes	Yes[a]	NR[b]	Yes	NR[b]	Yes[a]	NR[b]	Yes[c]	Yes[a]	NR[b]	Yes
Inserts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NR[b]	Yes	Yes
Built-in cores	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Molded-in holes	Yes	Yes	Yes	Yes[d]	Yes	Yes	Yes	Yes	No	Yes	Yes
Bosses	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Fins or ribs	Yes	Yes	Yes	Yes	No[e]	Yes	No[f]	Yes	Yes	Yes	Yes
Molded in designs and nos.	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Surface finish[g]	1–2	2	1–2	1–2	5	1	4–5	2–3	1–3	1–2	4–5
Overall dimensional tolerance (±)	0.01	0.001	0.001	0.005	0.005	0.001	0.005	0.01	0.01	0.001	0.02

[a] Special mold required.
[b] Not recommended.
[c] Only flexible material.
[d] Only direction of extrusion.
[e] Possible with special techniques.
[f] Fusing premix/yes.
[g] Rated 1 to 5 (1 = very smooth. 5 = rough).

Table 5. Guide to Decorating Processes.

	Economics	Aesthetics	Product Design	Chemistry	Manufacturing	Comments
Done in the mold						
1. Engraved mold	Unit cost low; labor cost low; investment moderate	Limited	Unrestricted	Not critical Good durability	No extra operations	Best for simple lettering and texture
2. In-mold label	Unit cost high; labor cost high; investment none to moderate	Unlimited	Somewhat restricted	Critical Good durability	Longer molding cycles	Good for thermoplastics and thermosets; automatic loading equipment becoming available
3. Inserted nameplates	Unit cost high; labor cost high; investment moderate	Partially limited	Restricted	Not critical Good durability	Longer molding cycles	Allows three-dimensional as well as special effects
4. Two-shot molding	Unit cost high; labor cost high; investment moderate to high	Limited	Somewhat restricted	Not critical Good durability	Two molding operations	Good where maximum abrasion resistance necessary
Done after molding						
1. Appliqué	Unit cost high; labor cost high; investment moderate to high	Somewhat limited	Unrestricted	Not critical Good durability	Hand operation	Allows unusual effects
2. Electrostatic	Unit cost low to moderate; labor cost low; investment moderate to high	Limited	Somewhat restricted	Critical Moderate to good durability		Dry process, no tool contact with product
3. Flexoraphic	Unit cost low; labor cost low; investment moderate to high	Somewhat limited	Restricted Moderate durability	Critical	Automates well	Wet process, tool contacts product; sometimes requires topcoat
4. Hand painting	Unit cost high; labor cost high; investment low	Somewhat limited	Unrestricted	Critical Good durability	Hand operation	Wet process, tool contacts product

Table 5. Continued.

	Economics	Aesthetics	Product Design	Chemistry	Manufacturing	Comments
5. Heat transfer	Unit cost low to moderate; labor cost low to moderate; investment low to moderate	Unlimited	Somewhat restricted	Critical Good durability	Requires little floor space	Dry process, tool contacts product Multicolor graphics
6. Hot stamping	Unit cost low; labor cost low to moderate; investment low to moderate	Limited	Somewhat restricted	Critical Good durability	Requires little floor space	Dry process, tool contacts product Produces bright metallics
7. Labeling	Unit cost low to moderate; labor cost low to moderate; investment low to high	Unlimited	Somewhat restricted	Less critical Moderate to good durability	Adaptable to many situations	Dry process, no tool contact with product at times Multicolor graphics
8. Metallizing	Unit cost moderate to high; labor cost moderate to high; investment high	Limited	Somewhat restricted	Critical Good durability	Requires special technological know-how	Wet and dry process, no tool contact with product Produces bright metallics
9. Nameplates	Unit cost high; labor cost moderate to high; investment low to moderate	Unlimited	Somewhat restricted	Less critical Good durability	Adaptable to many situations	Dry process, tool contacts product Multicolor graphics
10. Offset	Unit cost low; labor cost moderate; investment high	Unlimited	Restricted	Critical Moderate to good durability	Automates well	Wet process, tool contacts product Multicolor graphics
11. Offset intaglio	Unit cost low; labor cost moderate; investment moderate	Limited	Unrestricted	Critical Moderate to good durability	Requires little floor space	Wet process, tool contacts product New process

Table 5. Continued.

	Economics	Aesthetics	Product Design	Chemistry	Manufacturing	Comments
12. Silk screen	Unit cost moderate; labor cost moderate; investment moderate	Somewhat limited	Somewhat restricted	Critical Good durability	Flexible operation	Wet process, tool contacts product
13. Spray	Unit cost moderate; labor cost moderate; investment moderate to high	Limited	Unrestricted	Critical Good durability	Requires much floor space	Wet process, no tool contact with product
14. Wood-graining	Unit cost high; labor cost high; investment moderate to high	Specialized	Specialized	Critical Good durability	Mostly hand operated	Wet process, tool contacts products

Table 6. Guide to Decorating and Printing Processes.

Process	Description	Equipment	Applications	Effect
Conventional spray painting	Paint's sprayed by air or airless gun(s) for functional or decorative coatings. Especially good for large areas, uneven surfaces or relief designs. Masking used to achieve special effects.	Spray guns, spray booths, mask washers often required; conveying and drying apparatus needed for high production.	Can be used on all materials (some require surface treatment).	Solids, multicolor, overall or partial decoration, special effects such as wood-graining possible.
Electrostatic spray painting	Charged particles are sprayed on electronically conductive parts; process gives high paint utilization; more expensive than conventional spray.	Spray gun, high-voltage power supply; pumps; dryers. Pretreating station for parts (coated or preheated to make conductive).	All plastics can be decorated. Some work, not much, being done on powder coating of plastics.	Generally for one-color, overall coating.
Paint wiping	Paint is applied conventionally, then paint is wiped off. Paint is either totally removed, remaining only in recessed areas, or is partially removed for special effects such as wood-graining.	Standard spray-paint setup with a wipe station following. For low production, wipe can be manual. Very high-speed, automated equipment available.	Can be used for most materials. Products range from medical containers to furniture.	One color per pass; multicolor achieved in multistation units.
Roller coating	Raised surfaces can be painted without masking. Special effects like stripes.	Roller applicator, either manual or automatic. Special paint feed system required for automatic work. Dryers.	Can be used for most materials.	Generally one-color painting, though multicolor possible with side-by-side rollers.
Screen printing	Ink is applied to part through a finely woven screen. Screen is masked in those areas which won't be painted. Economical means for decorating flat or curved surfaces, especially in relatively short runs.	Screens, fixture, squeegee, conveyorized press setup (for any kind of volume). Dryers. Manual screen printing possible, for very low-volume items.	Most materials. Widely used for bottles; also finds big applications in areas like TV and computer dials.	Single or multiple colors (one station per color).
Hot stamping	Involves transferring coating from a flexible foil to the part by pressure and heat. Impression is made by metal or silicone die. Process is dry.	Rotary or reciprocating hot stamp press. Dies. High-speed equipment handles up to 6000 parts per hour.	Most thermoplastics can be printed; some thermosets. Handles flat, concave or convex surfaces, including round or tubular shapes.	Metallics, wood grains or multicolor, depending on foil. Foil can be specially formulated (e.g., chemical resistance).
Heat transfers	Similar to hot stamp but preprinted coating (with a release paper backing) is applied to part by heat and pressure.	Ranges from relatively simple to highly automated with multiple stations for, say, front and back decoration.	Can handle most thermoplastics. A big application area is bottles. Flat, concave or cylindrical surfaces.	Multicolor or single color; metallics (not as good as hot stamp).
Electroplating	Gives a functional metallic finish (matte or shiny) via electrodeposition process.	Preplate etch and rinse tanks; Koroseal-lined tanks for plating steps; preplating and plating chemicals; automated systems available.	Can handle special plating grades of ABS, PP, polysulfone, filled Noryl, filled polyesters, some nylons.	Very durable metallic finishes.

Table 6. Continued.

Process	Description	Equipment	Applications	Effect
Vacuum metallization	Depositing, in a vacuum, a thin layer of vaporized metal (generally aluminum) on a surface prepared by a base coat.	Metallizer, base- and top-coating equipment (spray, dip or flow), metallizing racks.	Most plastics, especially PS, acrylic, phenolics, PC, unplasticized PVC. Decorative finishes (e.g., on toys), or functional (e.g., as a conductive coating).	Metallic finish, generally silver but can be others (e.g., gold, copper).
Cathode sputtering	Uniform metallic coatings by using electrodes.	Discharge systems to provide close control of metal buildup.	High-temperature materials. Uniform and precise coatings for applications like microminiature circuits.	Metallic finish. Silver and copper generally used. Also gold, platinum, palladium.
Spray metallization	Deposition of a metallic finish by chemical reaction of water-based solutions.	Activator, water-clean and applicator guns; spray booths, top- and base-coating equipment if required.	Most plastics. For decorative items.	Metallic (silver and bronze).
Tamp printing	Special process using a soft transfer pad to pick up image from etched plate and tamping it onto a part.	Metal plate, squeegee to remove excess ink, conical-shaped transfer pad, indexing device to move parts into printing area, dryers, depending on type of operation.	All plastics. Specially recommended for odd-shaped or delicate parts (e.g., drinking cups, dolls' eyes).	Single- or multicolor – one printing station per color.
In-the-mold decorating	Film or foil inserted in mold is transferred to molten plastics as it enters the mold. Decoration becomes integral part of product.	Automatic or manual feed system for the transfers. Static charge may be required to hold foil in mold.	Most plastics, especially polyolefins and melamines. For parts where decoration must withstand extremely high wear.	Single- or multicolor decoration.
Flexography	Printing of a surface directly from a rubber or other synthetic plate.	Manual, semi- or automatic press, dryers.	Most plastics. Used on such areas as coding pipe and extruded profiles.	Single- or multicolor.
Offset printing	Roll-transfer method of decorating. In most cases less expensive than other multicolor printing methods.	Ranges from low-cost hand presses to very expensive automated units. Drying, destaticizers, feeding devices.	Most plastics. Used in applications like coding pipe.	Multicolor print or decoration.
Valley printing	Uses embossing rollers to print in depressed areas of a product.	Embosser with inking attachment or special package system.	Used largely with PVC, PE for such areas as floor tiles, upholstery.	Generally two-color maximum.
Labeling	From simple paper labels to multicolor decals and new preprinted plastic sleeve labels.	Equipment runs the gamut from hand dispensers to relatively high-speed machines.	Can be used on all plastics. Used mostly for containers and for price marking.	All sorts of colors and types.

GUIDE TO PROCESSING BASICS AND OVERVIEW INTO THE FUTURE WITH PICTORIAL VIEWS

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These thirty-six figures and four tables provide a brief summary of the process of injection molding (IM) compared to other processes, such as the plastic melting action during the extrusion and blow molding processes.

IM is a simplified description (Figure 1) of a complicated process that is controllable within specific limits. The goal is continual improvement of the relationship of process, plastic, and product (Figures 2 and 3), and controlling this process (Figure 4).

IM is a repetitive process in which melted or plasticized plastic is injected or forced into a mold cavity, where it is held under pressure until removed in a solid state, basically duplicating the cavity of the mold (Figure 5). The mold may consist of a single cavity or a number of similar or dissimilar cavities, each connected to flow channels or "runners" that direct the flow of the melt to the individual cavities (Figure 6). Three basic operations exist: (1) raising the plastic temperature in the injection or plasticizing unit so that it will flow under pressure, (2) allowing the plastic melt to solidify in the mold, and (3) opening the mold to eject the molded product.

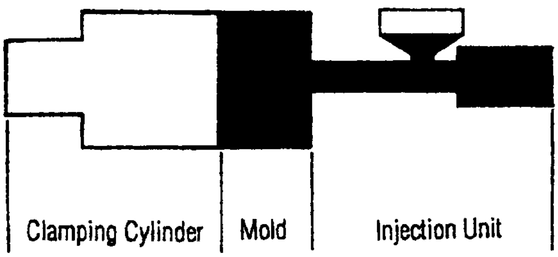


Fig. 1. IM Basic Elements. (All figures in this article are taken from the source: DVR, Injection Molding Newsletter, Society of Plastics Engineers)

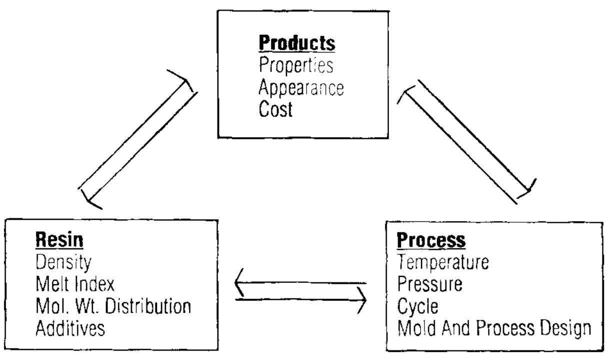


Fig. 2. Interrelate Triangle.

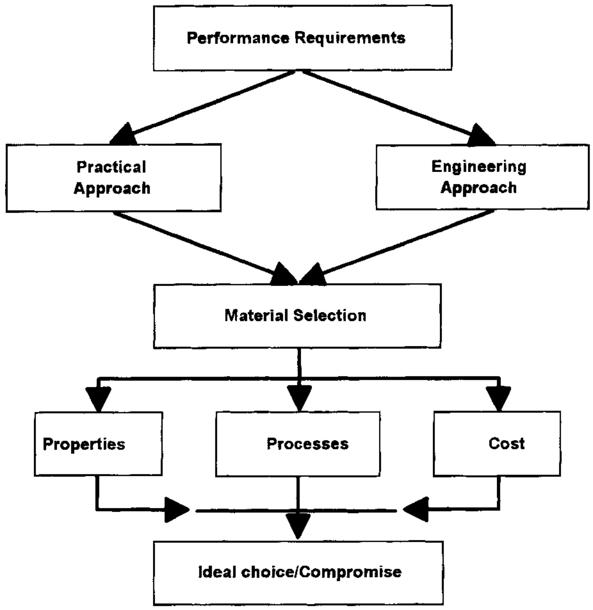


Fig. 3. Ideal Choice/Compromise.

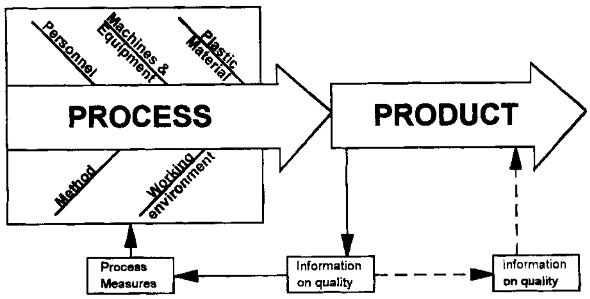


Fig. 4. Simplified Process Step.

These three steps are the operations in which the mechanical and thermal inputs of the injection equipment must be coordinated with the fundamental properties and behavior of the plastic being processed. They are also the prime determinants of the productivity of the process since manufacturing speed or cycle time (Figure 7) will depend on how fast the material can be heated, injected, solidified, and ejected. Depending on shot size and wall thicknesses, cycle times range from parts of a second to many minutes. Other important operations in the injection process range from feeding the IM machine (IMM), usually gravimetrically through a hopper, to the mold clamping system to ensure that high-quality products are produced (Figure 8).

An example of the complete IM operation is shown in Figure 9. This FALLO approach (Follow ALL Opportunities) summarizes what should be considered to ensure a good return on investment to produce all types and shapes of molded products. These important steps must come together properly to produce products consistently meeting

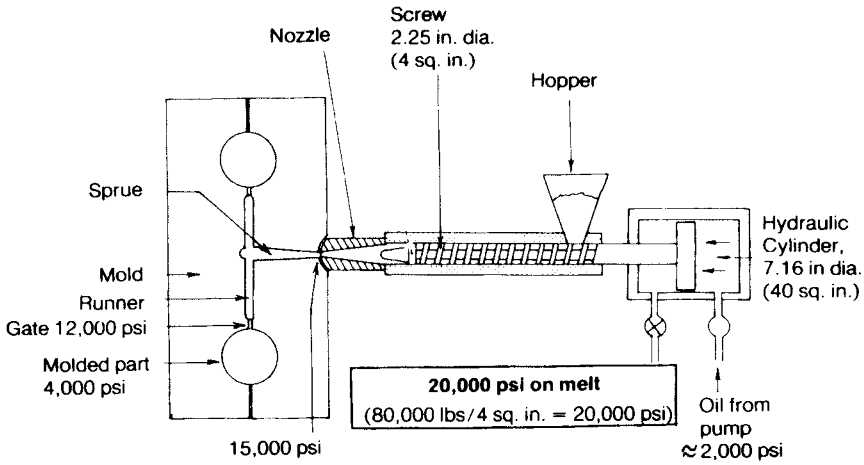


Fig. 5. Pressure Loading Melt.

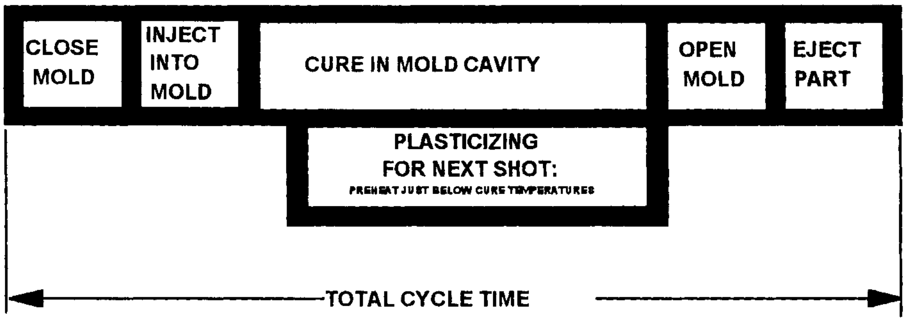


Fig. 6. Mechanical Load Profile.

performance requirements at the lowest cost: (1) design a mold (or die for extrusion) around the product, (2) put the proper auxiliary equipment around the mold (die), and (3) set up complete controls such as quality controls, troubleshooting guides, preventative maintenance, and operational safety procedures. To be effective, the evaluation of a product should proceed according to a logical step-by-step process (Figure 10) with a target of zero defects.

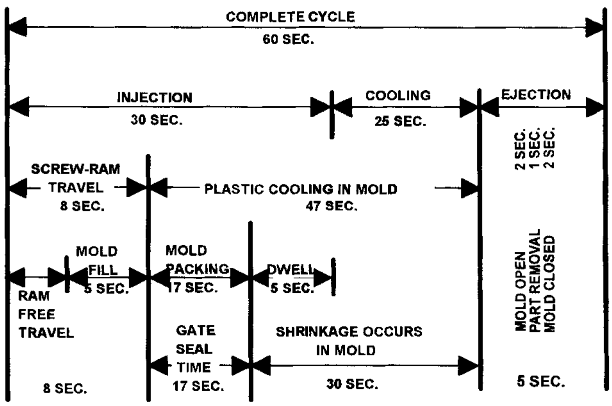


Fig. 7. Example of IM Cycle.

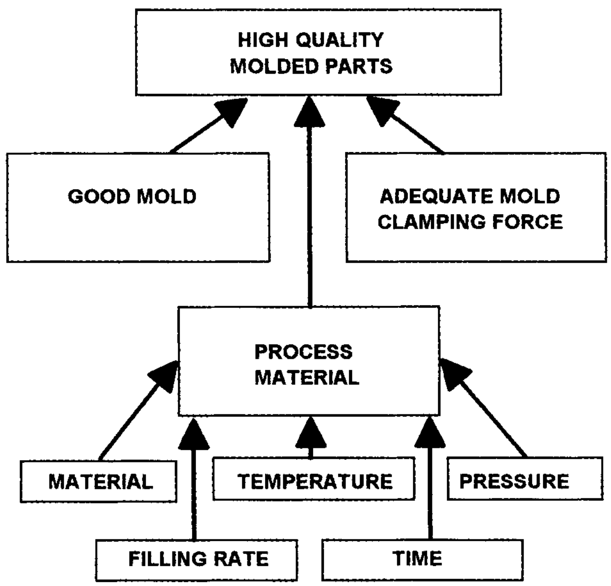


Fig. 8. Target Quality.

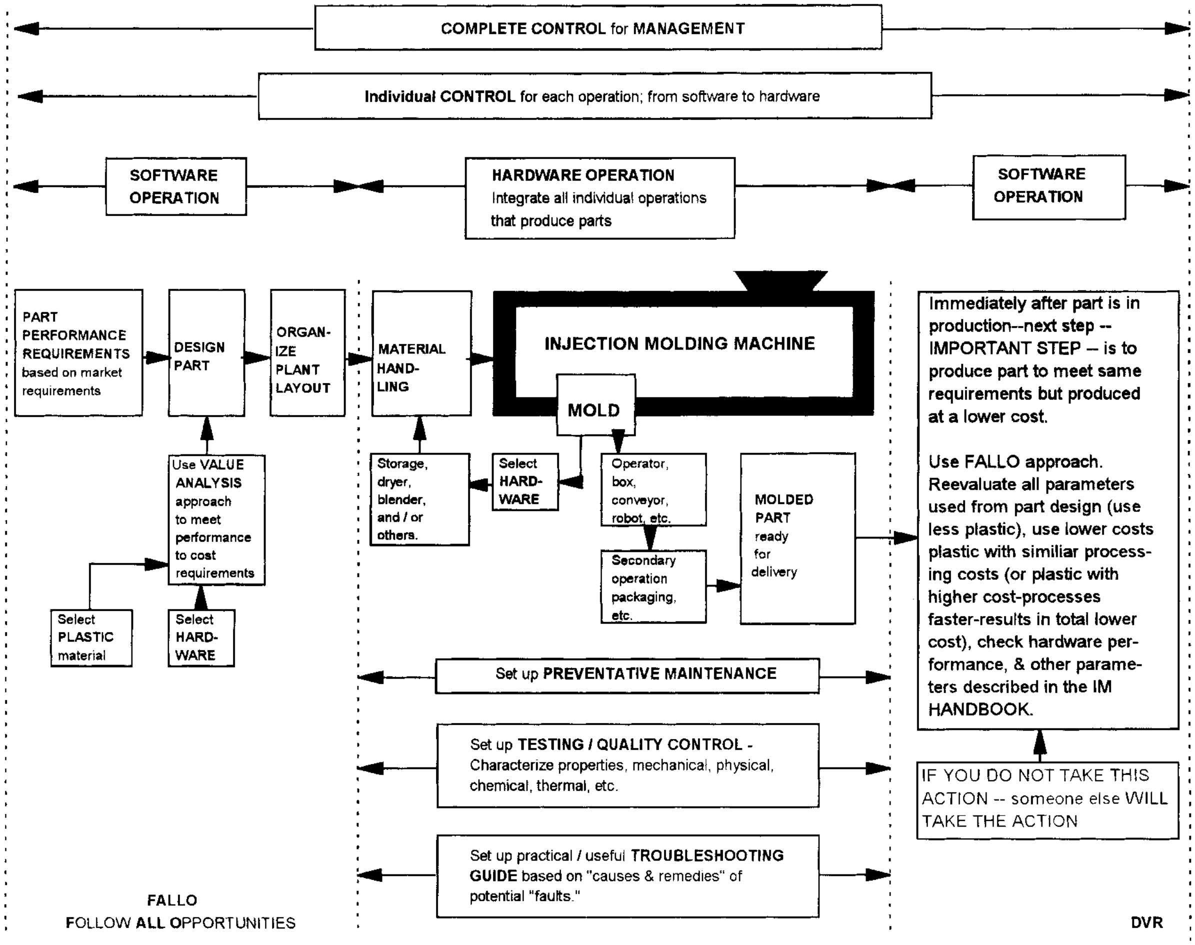


Fig. 9. FALLO Approach.

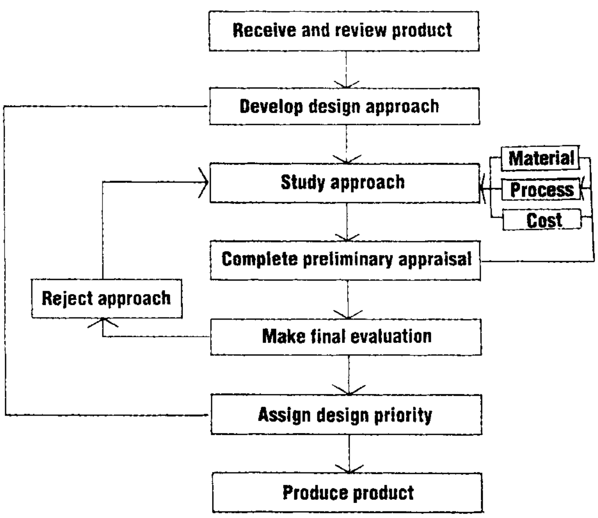


Fig. 10. Overall Product Approach.

People and Productivity

The recipe for productivity includes a list of ingredients such as R&D, new technologies, updated equipment, computer automation systems, and adequate, modern facilities. But the one ingredient that ties the recipe together is people. For example, computer software controls (CAD, CAM, CIIM, etc.) all provide a means of automating the manufacturing line (Figure 11). But to have the line run efficiently, people must properly use these guides. Equipment and plastic materials are not perfect; they require the human touch to ensure their repeatability.

Achievable processing plans begin with the recognition that smooth does not mean perfect. Perfection is an unrealistic ideal. It is a fact of life that the further someone is removed from a task, the more they are apt to expect perfection from those involved in the processing. The expectation of perfection can block genuine communication between workers, departments, management, customers, and vendors.

A smoothly run program creates a product that meets performance specifications, arrives on time, and falls within budget. Perfection is never reached; there is always

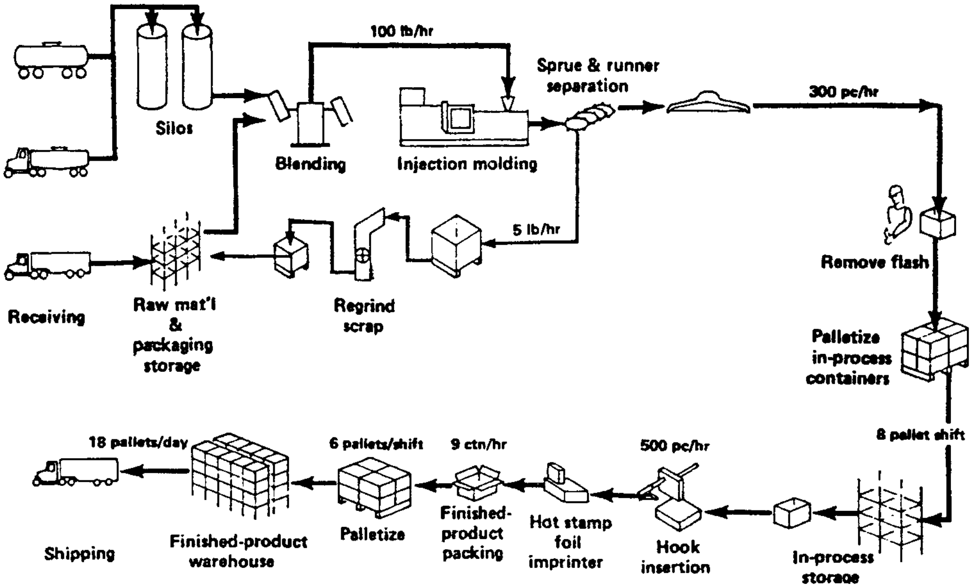


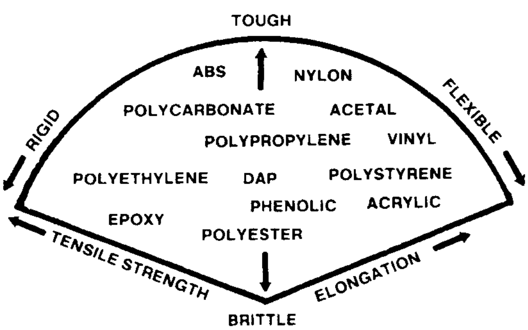
Fig. 11. Raw Materials to Products.

room for improvement. To live is to change, and to approach perfection is to have changed often (in the right direction).

Plastic Material

Literally many thousands of different plastics (also called polymers, resins, reinforced plastics, elastomers, etc.) are processed. Figure 11 is an example of the basic steps in a plant starting with incoming plastics to manufacturing the finished products and in turn packaging and shipping the products. Each of the plastics have their different melt behaviors, product performances (Figures 12 and 13), and costs.

There are basically two types of plastic materials molded. *Thermoplastics* (TPs), which are predominantly used (representing 90 percent of all plastics processed), basically can go through repeated heating/melting [usually



Note: With formulation changes (via additives, fillers, reinforcements, alloying, etc.) position of plastic can move practically any place in the "pie."

Fig. 12. Range of Properties.

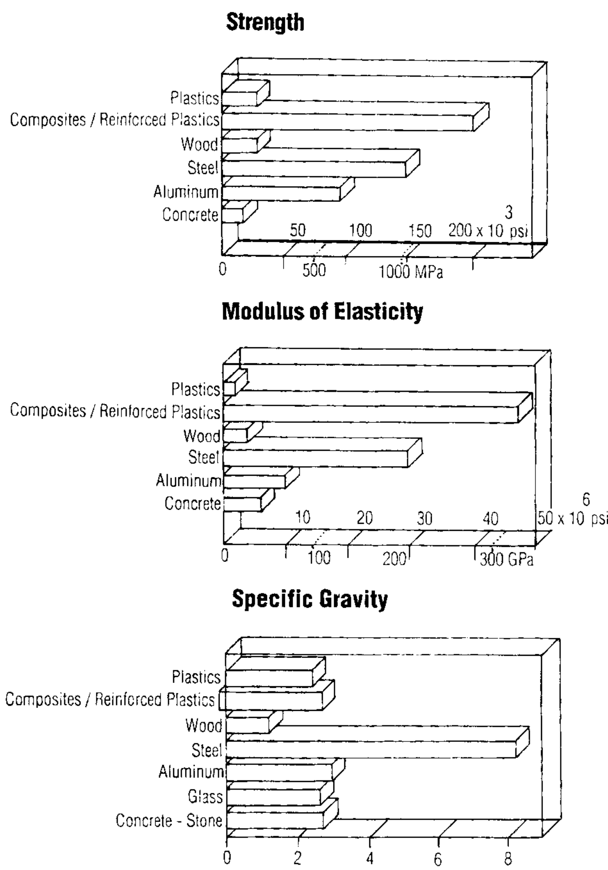


Fig. 13. Comparing Materials.

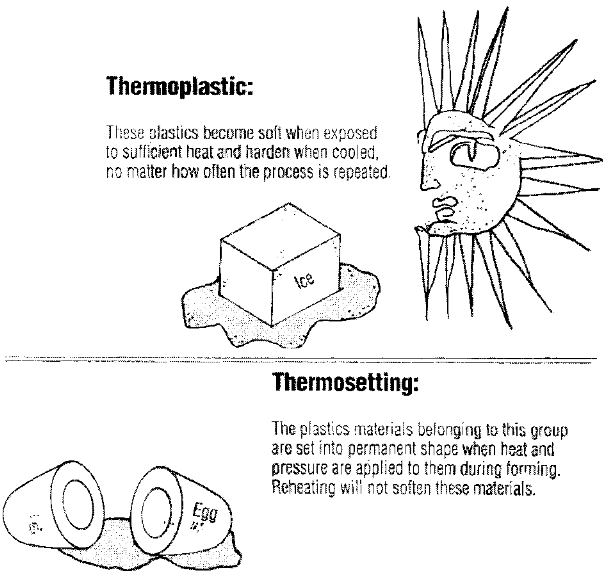


Fig. 14. Plastic Types.

at a low of 260°C (500°F)] to cooling/solidification cycles (Figures 14 and 15). The different TPs have different practical limitations to the number of heating-cooling cycles before appearance or properties are affected. *Thermosets* (TSs), on initial heating (usually at a low of 120°C (250°F)), become permanently insoluble and infusible. During heating they undergo chemical changes or cross-linking. Certain plastics require higher melt temperatures; some go up to at least 400°C (752°F).

Extensive *compounding* of different amounts and combinations of additives (colorants, flame retardants, heat and light stabilizers, and so on), fillers (calcium, carbonate, and so on), and reinforcements (glass fibers, glass flakes, graph-

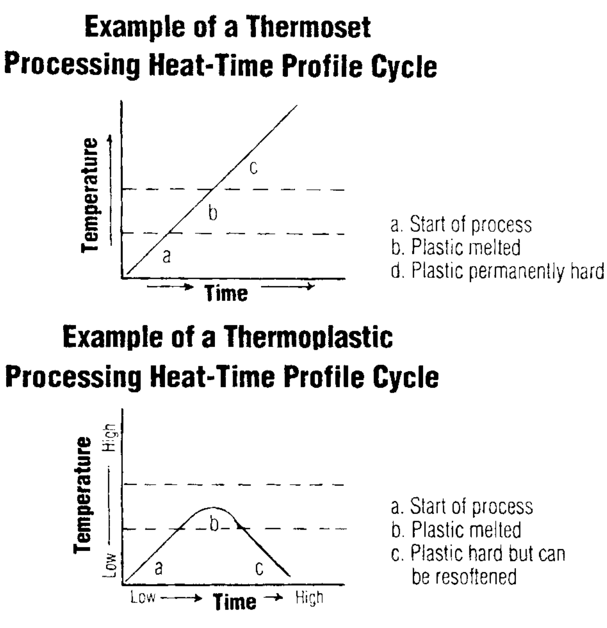


Fig. 15. Melt Profiles.

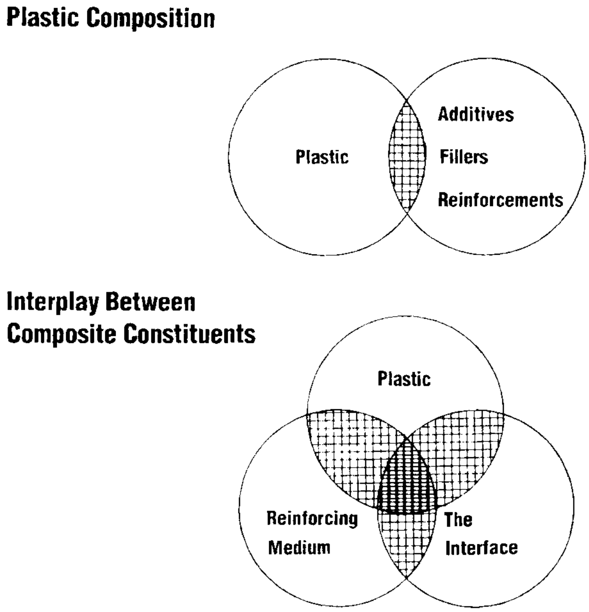


Fig. 16. Plastics Compositions.

ite fibers, and so on) are used with plastics (Figure 16). Compounding also embraces the mixing (*alloying, blending*) of two or more plastics that may be miscible or immiscible with or without additives.

With TPs, the mold is kept at a temperature below the solidifying point of the plastic. This approach causes the injected hot melt to initially start a surface "freezing" in the cavity followed with forming the solid product. After a sufficient cooling time, the mold opens, and the part is ejected. When processing TSs (from the injection/plasticizer), the hot melt entering the heated mold initially is permitted to remain below the temperature where it would cause premature solidification due to its exothermic reaction. After properly filling the cavity, the mold's higher temperature causes the melt to reach its final chemical cross-linking action, resulting in the melt's solidification.

Commodity and Engineering Plastics

By using different additives, fillers, and so on with the different plastics, more than 17,000 compounds are commercially available worldwide. They are used in the different processes to meet the processes' specific melt-flow characteristics or provide cost-to-product performance advantages. They are classified as commodity plastics or engineering plastics. Commodities such as PEs, PVCs, PPs, and PSs (see Appendix A, List of Abbreviations) account for over two-thirds of plastics sales.

Engineering plastics are characterized with meeting higher or improved performances. Half a century ago the dividing line costwise was about \$0.15/lb; now it is about \$1.00/lb. Examples of engineering plastics are PAs, PCs, ABS, and PEEK. Many of the TS plastics are of the engi-

Table 1. Plastics Morphology. (All tables in this article are taken from the source: DVR, Injection Molding Division Newsletter, Society of Plastics Engineers)

Property	Crystalline	Amorphous
Melting or softening	Fairly sharp melting point	Softens over a temperature range
Density (same plastic)	Increases as crystallinity increases	Lower that for crystalline plastic
Heat content	Greater	Lower
Volume change on heating	Greater	Lower
After-molding shrinkage	Greater	Lower
Effect of orientation	Greater	Lower
Compressibility	Often greater	Sometimes lower

neering type. Historically, as more competition and production occurs for certain engineering plastics, their costs go down and they become commodity plastics.

Morphology and Performance

Processability and performance of TPs, such as meeting product tolerance requirements and mechanical properties, are influenced by factors such as molecule size or weight, molecular distribution, and shapes or structures of individual molecules. They are formed by aligning themselves into long chains of molecules, sometimes with branches or lateral connections to form complex shapes. All these forms exist in either two or three dimensions. Because of their geometry, or *morphology*, some of these molecules can come closer together than others. These are identified as *crystalline* (such as PE, PP, and PA); the others are *amorphous* (such as PMMA, PS, SAN, and ABS). Table 1 provides examples of their characteristics. Morphology occurs with TPs but not TSs. When TSs are processed, their individual chain segments are strongly bonded together during a chemical reaction that is irreversible. Table 2 provides examples of thermal properties for TPs compared to some other common materials.

Plastics are either truly homogeneous, amorphous solids or heterogeneous, semicrystalline solids. There are no purely crystalline plastics since so-called crystalline materials also contain different amounts of amorphous material; semicrystalline is technically more accurate. Various methods of defining and evaluating plastics are used such as their *molecular weight distribution* (MWD). A narrow MWD enhances the performance of plastic products. MWD effects melt-flow rates.

Melt Flow and Rheology

Rheology is the science that deals with the deformation and flow of matter under various conditions; an example is plastic melt flow. The rheology of plastics, particularly TPs, is complex but manageable. These materials combine the properties of an ideal viscous liquid (pure shear deformations) with those of an ideal elastic solid (pure elastic deformation). Plastics are therefore said to be *viscoelastic* (Figure 17). The mechanical behavior of plastics is dominated by the viscoelastic phenomena such as tensile strengths, elongation at breaks, and rupture energy. The viscous attributes of melt flows are very important considerations during any processing system.

The *non-Newtonian* flow of plastics (solid line in Figure 18) is compared to that of the relatively straight *Newtonian* line of water. *Viscosity* is a material's resistance to viscous *deformation* (flow). The resistance of elastic deformation is the *modulus of elasticity* (E). Not only are there two classes of deformation; there are also two modes in which deformation can be produced—simple shear and simple tension. The actual action during melting, as in a screw plasticator (injection unit), is extremely complex with all types of shear-tension combinations. Together with screw design, deformation determines the pumping efficiency of the plasticator and controls the relationship between output rate and pressure drop through the melt flow to solidification and ejection of the product.

Plasticating

Many methods are used to melt or plasticate the plastics. The most common is the *single-stage* or the *reciprocating* single plasticating screw-barrel system (Figure 5). Melt is fed into a shot chamber (front of screw). This motion generates controllable low pressure (usually 50 to 300 psi (0.34 to 2.07 MPa)), which causes the screw to retract. When a preset device (such as a screw position transducer) is activated, the *shot size* is met, and the screw usually stops rotating. At a preset time the screw acts as a ram to push the melt into the mold. Depending on the plastics melt-flow characteristics, injection pressure at the nozzle takes place from 2,000 to 30,000 psi (14 to 200 MPa). A required pressure is basically determined by the plastic being processed and melts pressure required in the cavity, taking into account that pressure drops off as the melt travels in the mold. Molds are designed to meet different requirements. They include hot-runners or cold-runners (TPs and TSs) with different lengths of runners, gates, and so on. Adequate *clamping pressure* must be used to eliminate the mold from opening (*flashing*) during and after the filling of the cavity.

Other IM methods include different arrangements of *two-stage screws*. As an example, one of its stages is devoted to the melting and mixing through a rotating screw acting as an extruder where a melt continuously is produced.

Table 2. Thermal Properties.

Plastics Morphology C = crystalline A = amorphous		Density g/cm^3 (lb/ft^3)	Melt Temperature T_m °C (°F)	Glass Transition Temperature, T_g °C (°F)	Thermal Conductivity 10^{-4} cal/s cm °C (Btu/lb °F)	Heat Capacity cal/g °C (Btu/lb °F)	Thermal Diffusivity 10^{-4} cm^2/s (10^{-3} ft^2/h)	Thermal Expansion 10^{-6} cm/cm °C (10^{-6} in/in.°F)
PP	C	0.9 (56)	168 (334)	5 (41)	2.8 (0.068)	0.9 (0.004)	3.5 (1.36)	81 (45)
HDPE	C	0.96 (60)	134 (273)	−110 (−166)	12 (0.290)	0.9 (0.004)	13.9 (5.4)	59 (33)
PTFE	C	2.2 (137)	330 (626)	−115 (−175)	6 (0.145)	0.3 (0.001)	9.1 (3.53)	70 (39)
PA	C	1.13 (71)	260 (500)	50 (122)	5.8 (0.140)	0.075 (0.003)	6.8 (2.64)	80 (44)
PET	C	1.35 (84)	250 (490)	70 (158)	3.6 (0.087)	0.45 (0.002)	5.9 (2.29)	65 (36)
ABS	A	1.05 (66)	105 (221)	102 (215)	3 (0.073)	0.05 (0.002)	3.8 (1.47)	60 (33)
PS	A	1.05 (66)	100 (212)	90 (194)	3 (0.073)	0.05 (0.002)	5.7 (2.2)	50 (28)
PMMA	A	1.20 (75)	95 (203)	100 (212)	6 (0.145)	0.56 (0.002)	8.9 (3.45)	50 (28)
PC	A	1.20 (75)	266 (510)	150 (300)	4.7 (0.114)	0.5 (0.002)	7.8 (3.0)	68 (38)
PVC	A	1.35 (84)	199 (390)	90 (194)	5 (0.121)	0.6 (0.002)	6.2 (2.4)	50 (28)
Aluminum		2.68 (167)	1,000		3,000 (72.5)	0.23	4,900 (1900)	19 (10.6)
Copper/bronze		8.8 (549)	1,800		4,500 (109)	0.09	5,700 (2200)	18 (10)
Steel		7.9 (493)	2,750		800 (21.3)	0.11	1,000 (338)	11 (6.1)
Zinc alloy		6.7 (418)	800		2,500 (60.4)	0.10	3,700 (1430)	27 (15)
Maple wood		0.45 (28.1)	400 burns		3 (0.073)	0.25	27 (10.5)	60 (33)

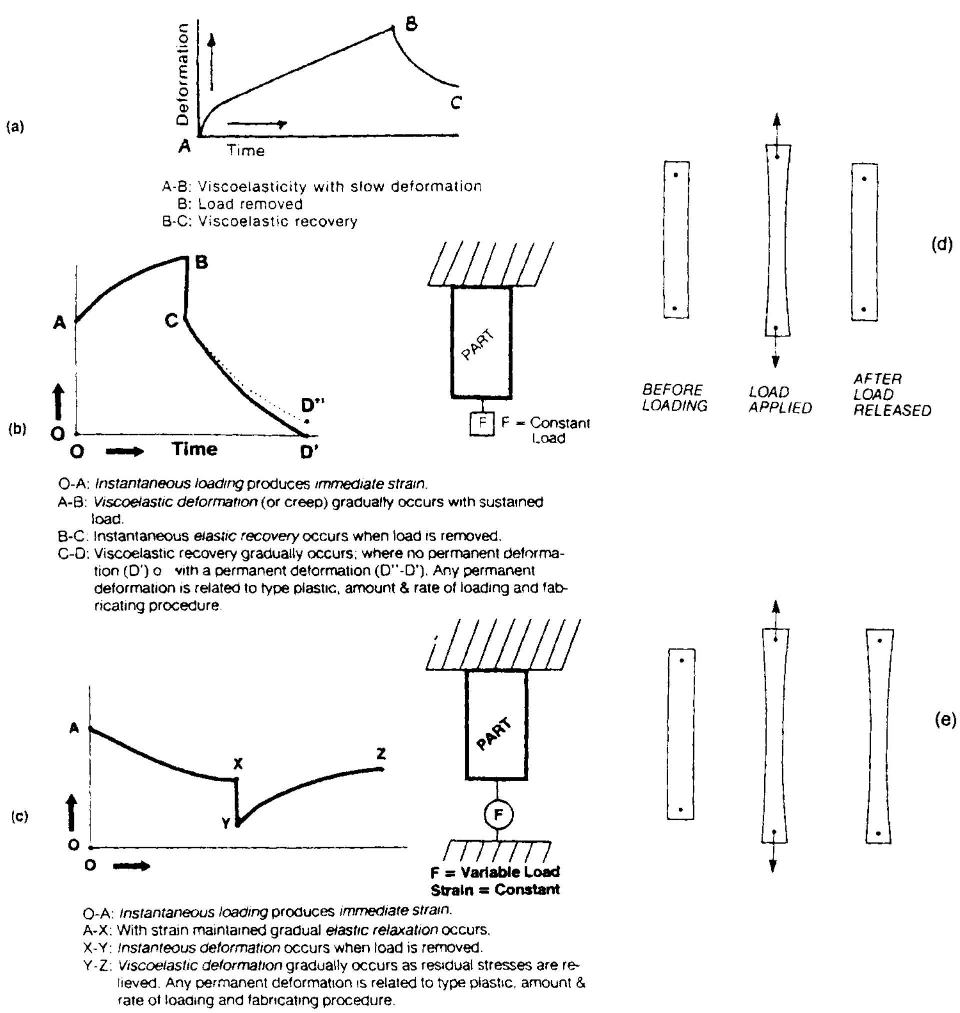


Fig. 17. Viscoelastic Behaviors.

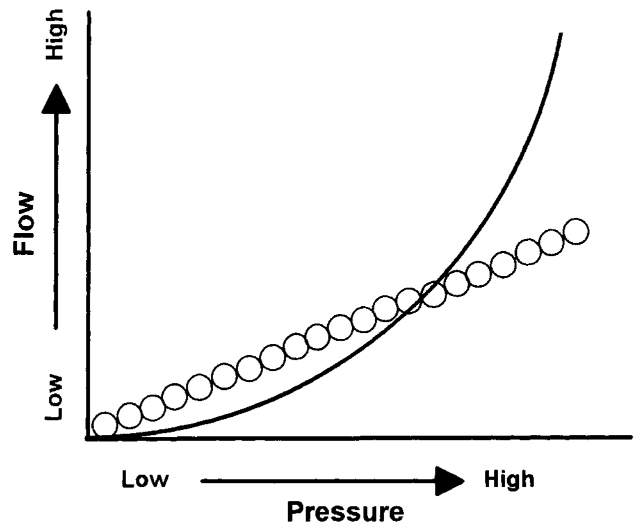


Fig. 18. Plastics Rheology.

This screw does not require a reciprocating action (as in a single-stage IMM) since it conveys melts only by means of some type of diverter mechanism or valve into a "holding" or injection cylinder. When a sufficient quantity of melt has been transferred, the diverter valve again shifts to create a flow path from the injection cylinder into the mold. The second-stage (injection stage) provides the pressure of the melt (shot size) into the mold cavity. After injection is completed, the diverter valve shifts to direct the melt-flow path from its first-stage into the second-stage holding cylinder, and this operating cycle continually repeats.

The various IMM designs that are used to process plastics each provide advantages, such as reducing product weight (reducing plastic consumption), eliminating or minimizing molded-in stresses, and improving performances and tolerances. Various *gas-injection molding machine* (GIMM) systems involve the injection of an inert gas, usually nitrogen, into the melt as it enters the mold. The gas forms a series of interconnecting hollow channels within the melt. The gas pressure at about 4,300 psi (30 MPa) is maintained through the cooling cycle. In effect, the gas packs the plastic against the cavity wall.

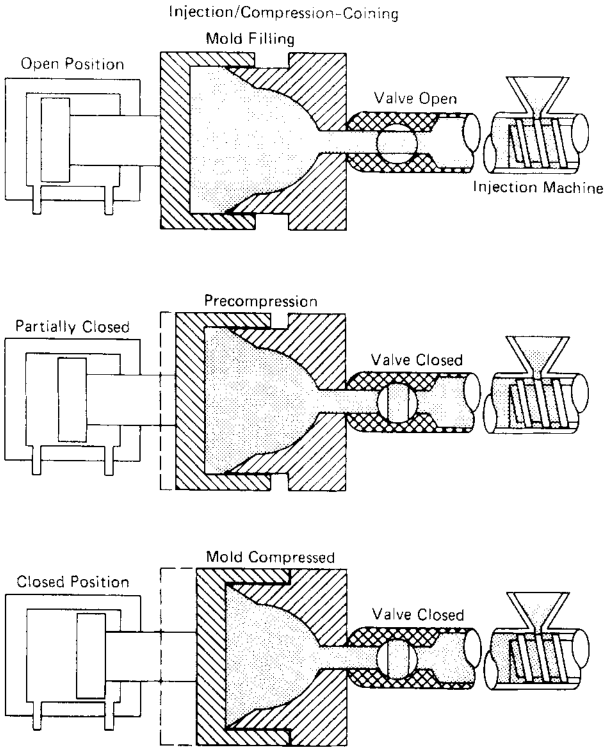


Fig. 19. Injection/Compression.

Another design is *injection-compression molding*, also called *injection stamping* and more often *coining*. It uses a compression type mold having a male plug that fits into a female cavity (Figure 19). After a short shot (relatively no pressure in cavity) enters the preopened or preclosed cavity mold, its stress-free melt is compressed to mold the finished product. Other systems include *coinjection, two-color IM, counterflow IM, multilive IM, oscillatory IM, reaction IM, liquid IM, foam IM, fusible and soluble core IM, tandem IM, injection blow molding, IM with rotation, continuous IM* (Velcro strips, etc.), *metal-plastic IM, vacuum IM*, and so on.

Screw Design

The primary purpose for using a screw is to take advantage of its mixing action. The motion of the screw should keep any difference in melt temperature, melt uniformity, and melt output to a minimum prior to entering the mold. Heat is applied from heater bands around the barrel and the mixing action that occurs when plastic moves via the screw (Figures 5 and 20). Both conduction and mechanical friction accomplish heating during screw rotation. As summarized in Figure 21, different controls during IM, such as back pressure and screw RPM, influence melt characteristics.

Generally, most IMM use a single constant-pitch, metering-type screw for handling most of the plastics. Basically a screw has the three sections of *feed, melting (transition), and metering* (Figure 20). The feed section, which is at the back end of the screw (where plastics first enter), can occupy from about zero to 75 percent of the screw length but usually occupies 50 to 75 percent. Its length essentially depends on how much heat has to be added to the plastic that enters the hopper where it may be preheated.

The melting (transition) section is where the softened plastic is transformed into a continuous melt. It can occupy from 5 to 50 percent of the screw length. This usual compression zone has to be sufficiently long to make sure that the plastic is melted. A straight compression-type screw is one having no feed or metering section. For certain plastics, particularly TSs, there tends to be no compression zone since overheating and solidification of the melt could occur in the screw or barrel.

In the metering section, the plastic is smeared and sheared to give a melt its final uniform composition and temperature for delivery to the mold. As high shear action will tend to increase the melt's temperature, the length of the metering section is dependent on the plastic's heat sensitivity and if any additional mixing is required. For certain heat-sensitive plastics very little or no metering action can be tolerated. For other plastics it averages about 20 to 25 percent of the screw length. Both the feed and metering sections usually have a constant cross-section (zero compression ratios). However, the depth of the flight for the feed section is greater than that in the metering section. The screw's *compression ratio* can be determined by dividing the flight depth in the feed section by that in the metering section. Depending on plastics processed, ratios usually range from 0 to 4.

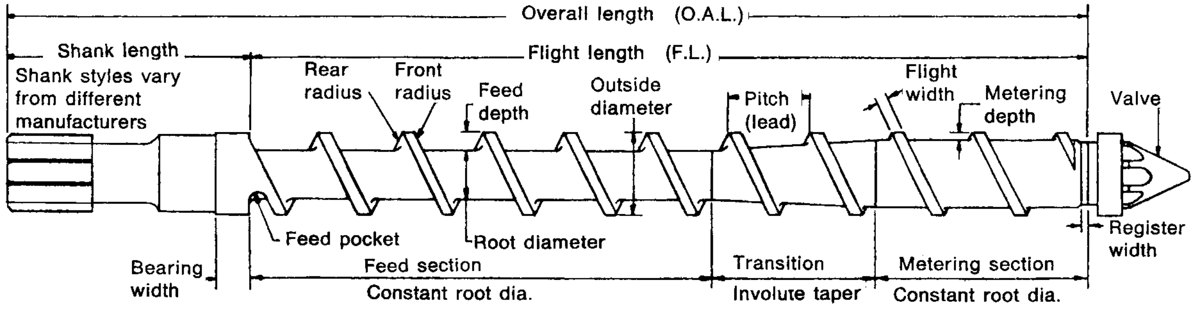


Fig. 20. Screw Nomenclature.

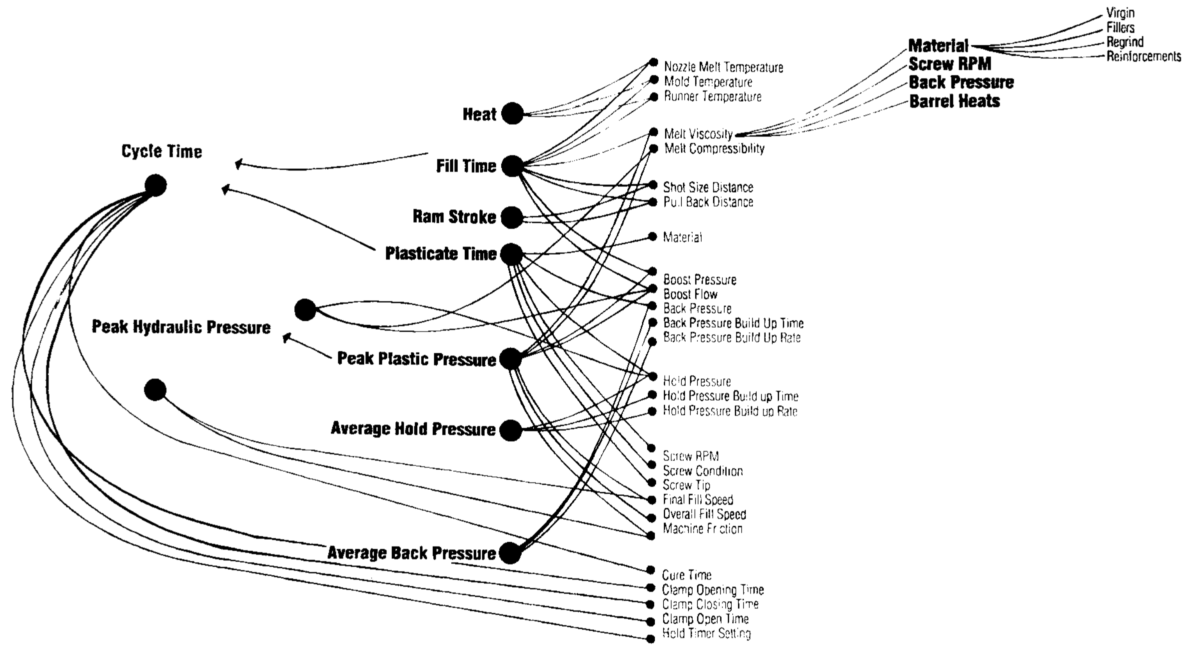


Fig. 21. IM Machine Controls.

Mold

A mold must be considered as an important part of IM. It is a controllable complex device providing different functions or capabilities to permit molding the desired product (Table 3). If not properly operated, handled, and maintained, it will not be an efficient operating device. Under pressure, hot melt moves rapidly through the mold. Basically, temperature-controlled water (with ethylene glycol if the water has to operate below its freezing point) circulates in the mold to remove heat from TPs; with TSs electrical heaters that are usually used within the mold provide the additional heat required to solidify the plastic melt in the cavity. Air is released from the cavity to eliminate melt burning or voids in the products.

Melt moving through the mold basically consists of properly designed *sprue, runner, gate,* and *cavity* (Figure 5). The sprue is the channel, cut in the stationary platen that transports the melt from the plasticator nozzle to the runner. In turn, melt flows through the gate and into the cavity. With a single cavity mold, usually no runner is used, so melt goes from the sprue to the gate.

In use are different runner systems to meet different processing requirements. The more popular are the *cold* and *hot runners*. With a TP cold runner, the melt from the sprue to the gate solidifies by the cooling action of the mold as the melt in the cavity solidifies. A hot runner for TP has the sprue to the gate insulated from the chilled cavity and remains hot so that the melt never cools; its next shot starts from the gate rather than the nozzle as in

Table 3. Examples of Mold Functions.

Mold Component	Functions Performed
Mod base	Locates cavity in its permanent or correct position
Guide pin	Aligns the two basic mold halves
Sprue bushing	Provides proper and leak-proof alignment with the plasticator nozzle
Runner	Directs melt from the sprue to cavity gate
Gate	Provides proper melt flow into the cavity
Vent	Trapped air and gas escapes from the cavity
Actuating device that operates mechanically, hydraulically, or electrically	Permits side holes or windows, undercuts, threaded sections
Water channel for TPs or heater to TSs	Provides proper cooling (TPs) or heating (TSs)
Ejector device that operates mechanically with pins, blades, plates, robots, with or without air	Required force or action is required to remove molded parts at the end of their cycle
Ejector return pin or other mechanical device	Used to return the ejector pin as mold closes after parts are ejected

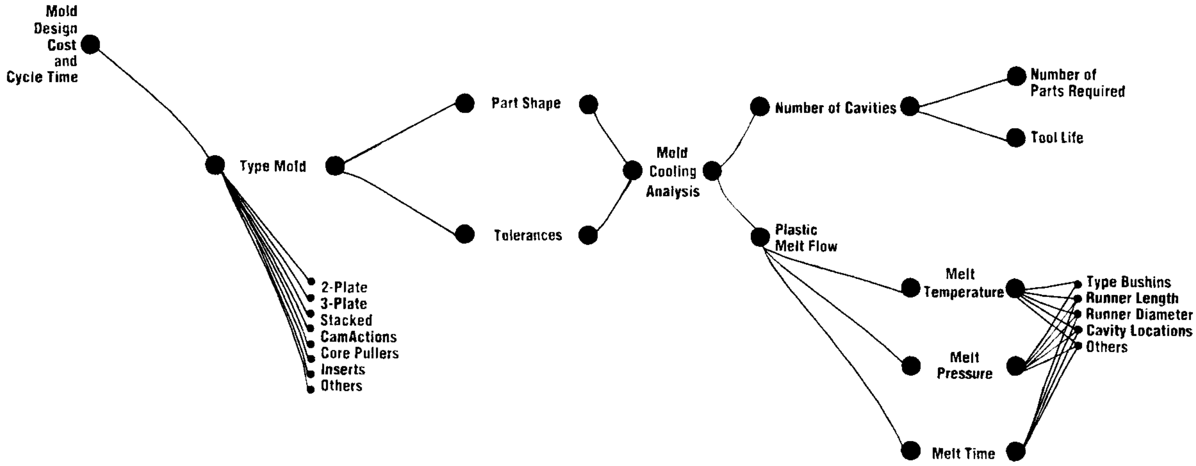


Fig. 22. IM Mold Controls.

a cold runner. With TS, when the melt solidifies, it is called a hot runner. The cold runner TS remains as a melt using a cooled insulated manifold; its next shot starts from the gate rather than the nozzle as in a TP hot runner.

Molds with different operating actions include sliders, unscrewing devices, and knockout systems to eject products as well as solidified runners at the proper time. These basic operations in turn require all kinds of interactions such as fill-time and hold pressure (Figure 22).

Processing

Processing steps are summarized in Figures 4, 7, 21, and 22. Figure 23 is an example for processing reinforced plastics (RPs). Different machine requirements or material conditions are set to ensure use of the most efficient IM process. Important in practically all operations are factors such as using unworn screws and properly dried plastics. Special dryers *vented barrels* are required in drying the TP *hygroscopic* materials (such as PC, PMMA, PUR, PET).

Use of *regrind* may have little effect on product performances (such as appearance, color, or strength). However, reduction in performance could occur with TPs such as the once-through shown in Figure 24. Granulated TSs can be used as additives or fillers in plastics; they are not remeltable.

The process of heating and cooling many TPs can be repeated indefinitely by granulating scrap, defective products, and so on. During these cycles the plastic develops a time-to-heat history or *residence time*. This action can significantly lose processing advantages and properties. Loss

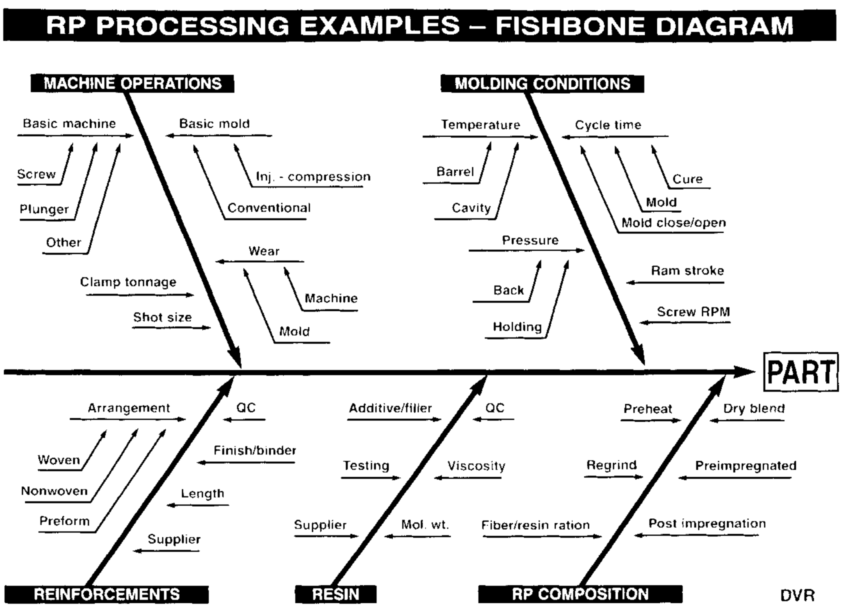


Fig. 23. Processing RPs.

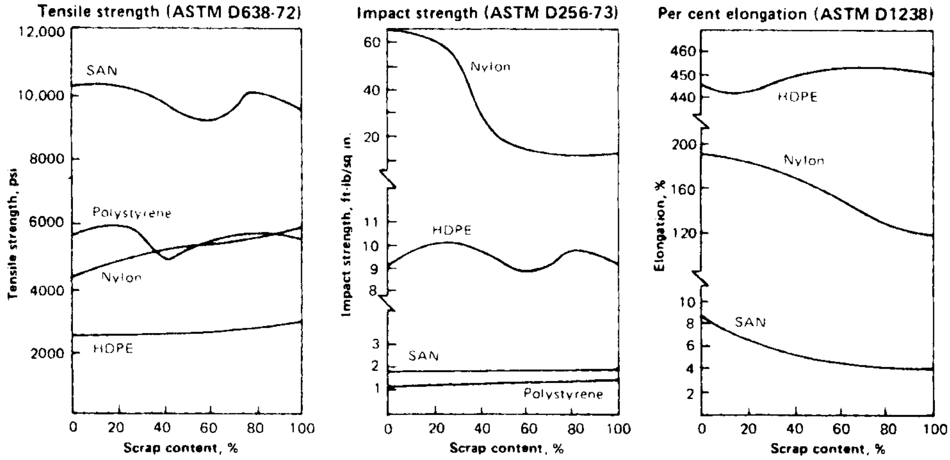


Fig. 24. Regrind Once Through.

may require compensation of product design, process setup, and material modification.

With all the types of plastics *IM troubleshooting guides* are set up to take fast, corrective action when products do not meet their performance requirements. Table 4 provides an example of errors in the mold and product design with possible consequences during processing or product performance. Troubleshooting guides can be incorporated in process control systems. (Troubleshooting guides are used with all the different processes.)

Process Control

Proper injection of plastic into the mold is influenced by several conditions (Figures 21 and 22). Any one or combinations of conditions can effect different parameters such as those going from the raw material being fed into the IMM, flow of melt, packing of mold cavity cycle time, to product performances. As an example, parameters that influence product tolerances involve (1) product design, (2) plastics used, (3) mold design, (4) IMM capability, and (5) molding cycle time. Examples of effects due to IMM and plastic material variables are shown in Figures 25 to 29.

Different types of machine process controls (PCs) can be used to meet different requirements based on the molder's needs. PC systems range from the unsophisticated *monitors* (alarm buzzes, light flash) to very sophisticated *program controllers* (personal computers (PCs) interrelate different IMM functions and melt process variables) (Figure 30). (Note that PC has different definitions; see Appendix A, List of Abbreviations.)

Knowledge of the machine and plastic capabilities are needed before an intelligent PC program can be developed. The use of PC or SPC (statistical PC) software con-

Table 4. Relate Error to Processing.

Faults	Possible Problems
Wrong location of gate	Weld line(s), flow line(s), melt jetting, air entrapment, voids, warping, stress concentrations, sink mark(s), etc.
Gates and/or runners too narrow	Short shot, overheating plastic, premature melt freezing, voids, etc.
Runners too large	Increased cycle time, plastic waste, pressure loss, etc.
Unbalanced cavity layout in multiple cavity mold	Unbalanced cavity pressure buildup, mold distortion, dimensional variation/poor shrinkage control, stresses, flash, etc.
Nonuniform cooling; not properly applied	Increased cycle time, distortion during ejection, high after shrinkage, stresses/warpage, poor part release, etc.
Poor or no venting	Use higher injection pressure, plastic burns or streaks, short shot, etc.
Poor ejection system or bad locations of ejector(s)	Poor mold release, part distortion or damage, changes or upsets molding cycle, etc.
Insufficient sprue to nozzle contact	Melt leakage occurs, mold wear, higher injection pressure required, poor cycle repeatability, etc.
Sprue to long	Pressure loss develops, longer molding cycle, requires increase in heat requirement, premature freezing of sprue, etc.
Draft of molded part too small	Poor mold release, part distortion, dimensional variation, etc.

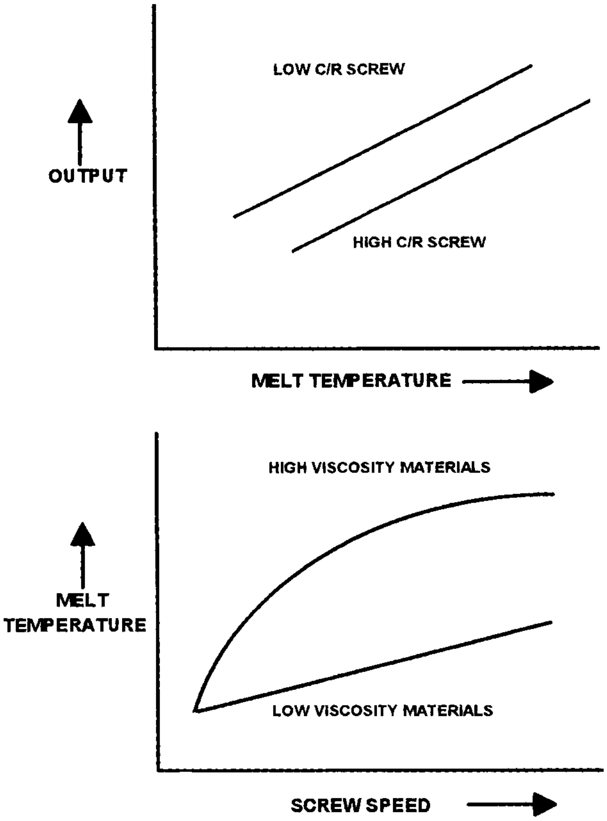


Fig. 25. Effects of IM Controls.

unsophisticated monitors (alarm buzzes)

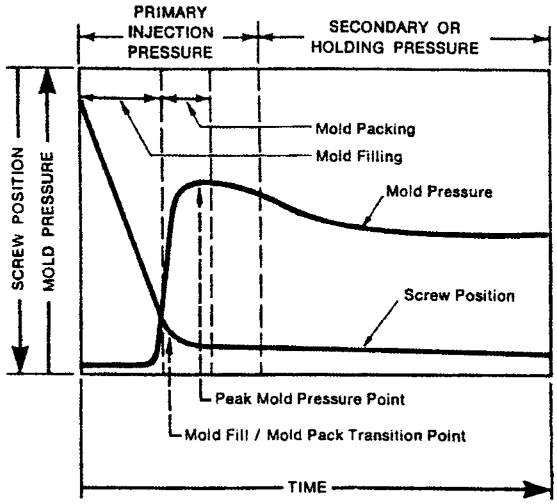


Fig. 27. Mold Pressure Profile.

tinually means understanding the endless new computer technology as it applies to basically melting plastic to produce the required products at the lowest cost.

Fine Tuning

The *computer-integrated injection molding* (CIIM) systems make it possible to target for (1) approaching a completely

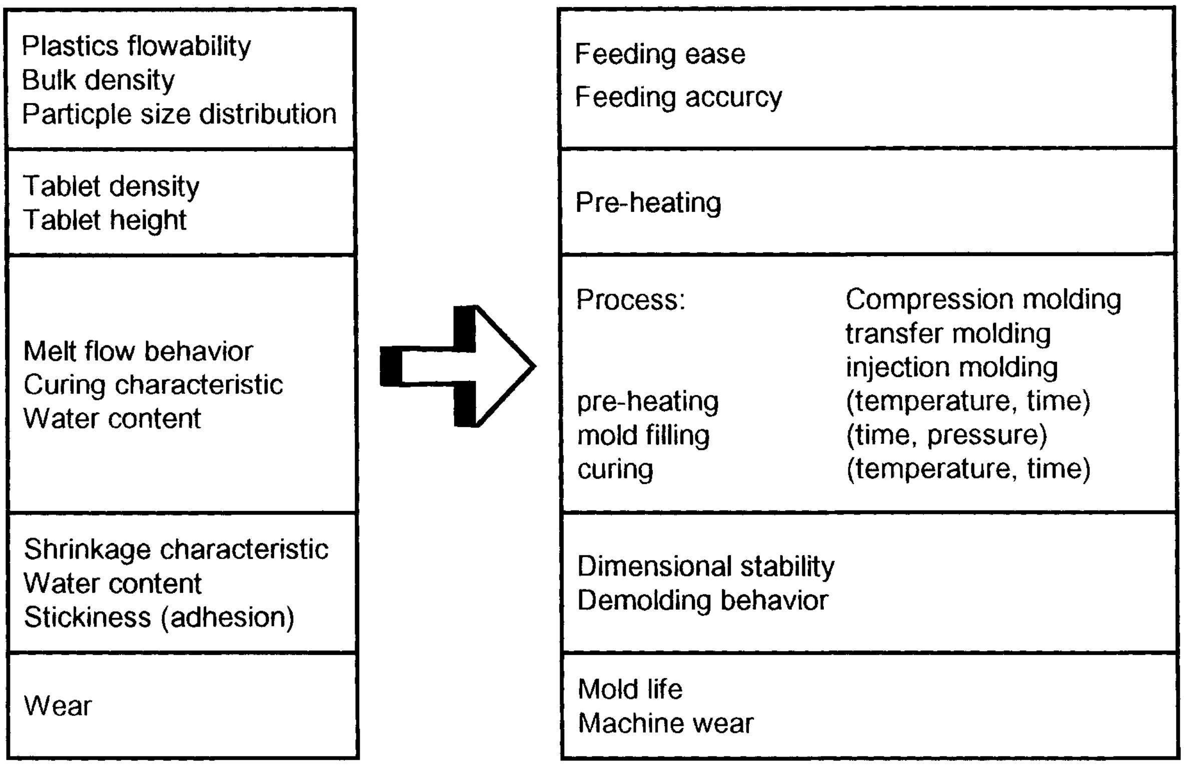


Fig. 26. Processing Behavior.

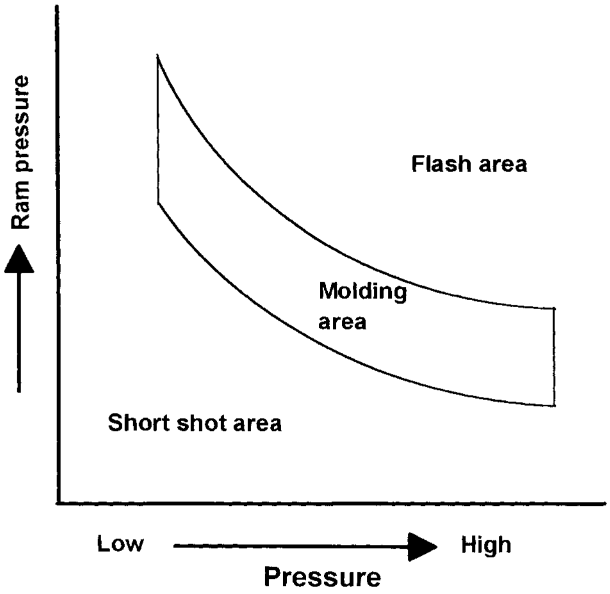


Fig. 28. Mold Area Diagram/2-D.

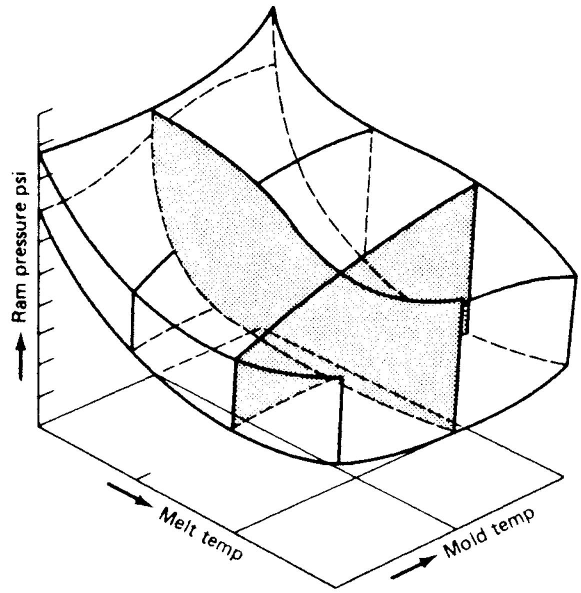


Fig. 29. Mold Volume Diagram, 3-D.

automated IM system, (2) simultaneously achieving high quality and zero defects, (3) increasing productivity, and (4) minimizing cost. They do this in several ways by basically enabling the molder to fine-tune all the relationships that exist with the many machine-setting and plastic or melt behaviors (Figure 30). These systems, when properly used by people, readily adapt to enhancing processing capabilities.

Once *processing variables* (machine and plastic) are optimized through computer simulation (rather than the usual trial-and-error method), these values are entered in computer programs in the form of a rather large number of machine settings. Establishing the initial settings during startup is inherently complex and time-consuming, but the many benefits of these systems are well recognized and accepted. IM can be effective only when the design of

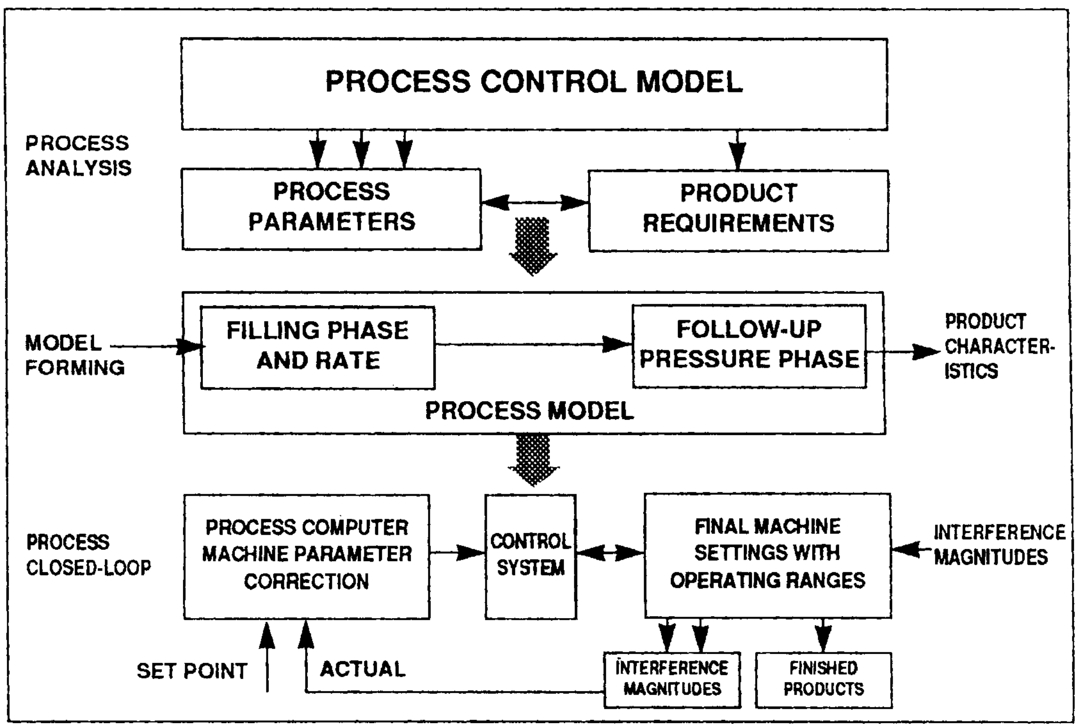


Fig. 30. IMM Functions.

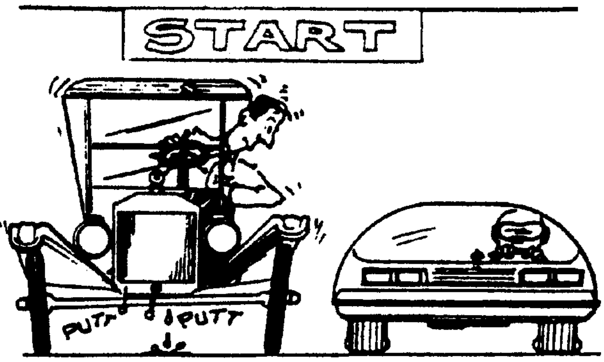


Fig. 31. Old Versus New Equipment.

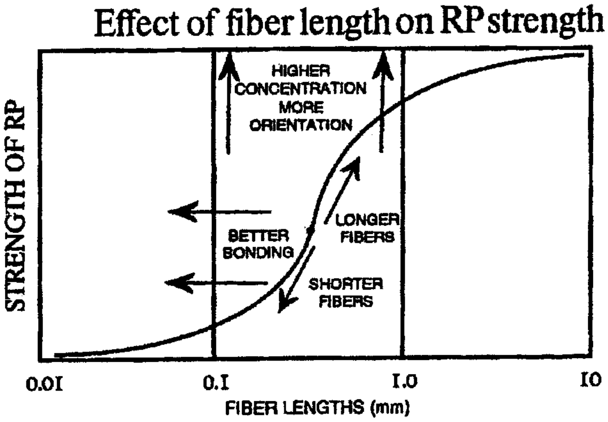


Fig. 33. Effect of Fiber Lengths on RP Strength.

the product and the mold are optimized with the correct processing conditions. Otherwise, a self-regulating IMM is confused and can provide conflicting instructions. Result could be disastrous, damaging the machine or the mold. Therefore, the efficient utilization of microprocessor control systems depends on the success of utilizing correct and optimum programs with knowledgeable people.

Purchasing and Handling Plastic

On the average, raw materials and their handling services incur at least half of the costs in plastic IM (as well as most other processes; noninjection molded reinforced plastic usually has at least half the cost in labor). Wages utilities, overhead, and capital equipment costs could account for the rest. All costs are important to evaluate and justify. As an example, in a high-production IM line, equipment costs could represent less than 5 percent of the total cost to produce products. There is nothing new in being economical and logical when purchasing equipment, but equipment should cost the least to operate while still meeting requirements (Figure 31).

It is therefore important to purchase the *raw materials* at favorable prices, have them delivered punctually (just-in-time or otherwise), provide the required handling systems, use as little as possible (design minimum wall thicknesses of products, do not overpack in cavity, and so on), and ensure that material conforms to the required specifications. Action is usually required to check materials received.

Warehousing requires that raw materials, additives, spare parts, molds, tools, molded products, and so on be stored and handled safely and economically. Various systems are available to meet different needs in warehousing. They can handle schemes for integrating the inward and outward flow of goods, order picking and transportation, factory administration, and process control for warehousing tasks.

Summary

IM (as does other plastics fabricating processes) provides the world with useful or required products consuming about 32 percent of all plastics. The processor is required to keep up to date and determine when changes are to be made to take advantage of continuing new developments in equipment (Figure 31) and materials (Figure 32). Factors such as *energy conservation* and expanding the use of

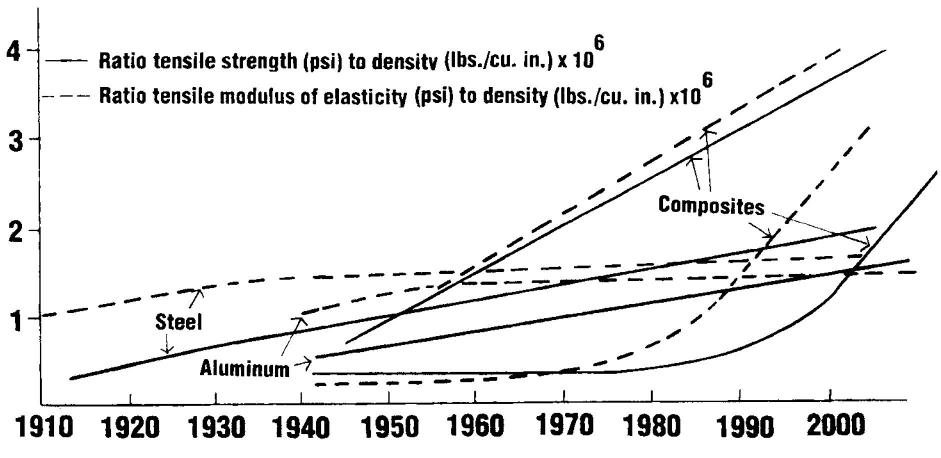


Fig. 32. RP Growth and Forecast.

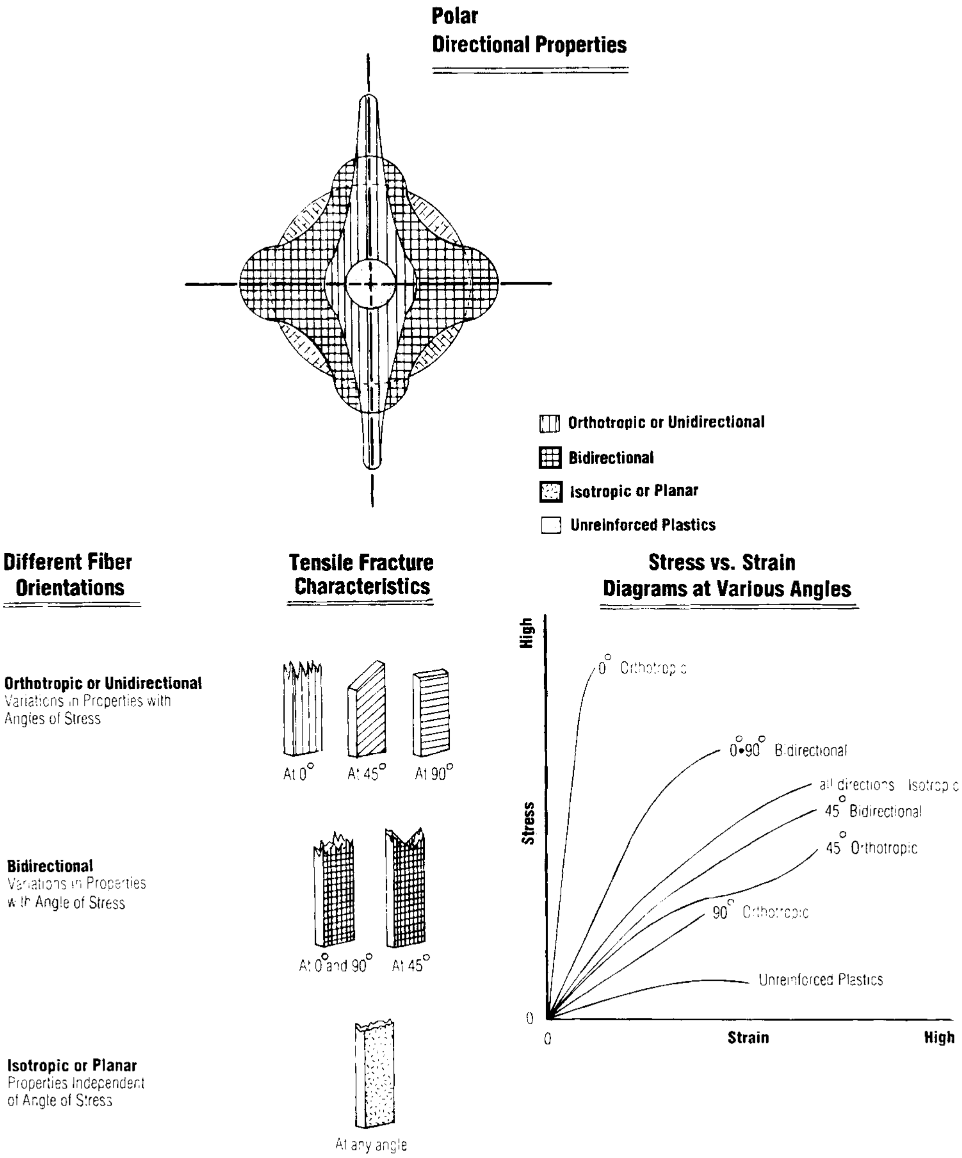
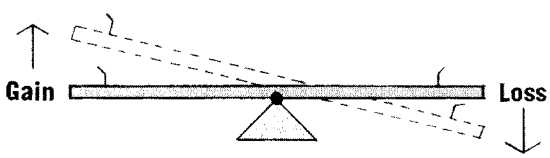


Fig. 34. RPs Directional Properties.

Become aware that for any gain there could be a loss not originally included in the design performance.



When you gain "something" there will be a loss ..... does that loss influence product performance (for any material: plastic, wood, steel, glass, etc.).

Fig. 35. A Judicious Balance.

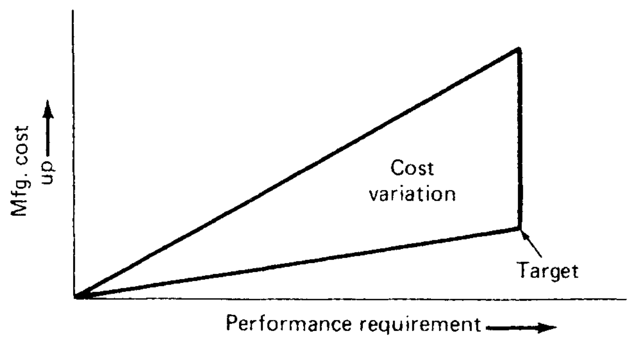


Fig. 36. Meet the Target.

reinforced plastics (RPs) provide more potential for product growth.

Already IM is the highest-volume method of any RP processed using milled or short glass fibers (Figure 33). Long-fiber materials such as bulk molding compounds have been used for about a half century using stuffer-ram feeders with ram or screw IMM plasticators. With in-mold layups of RPs, high-performance directional properties are achievable (Figure 34).

Although considerable talent can be brought to bear on processing and engineering aspects, economic questions will always exist. Cost problems are particularly acute when the technology that will be employed is not fully understood and much of the cost analysis is based on historical data, past experience, and individual accounting practices that are not properly updated. A *technical cost modeling* (TCM) system can be used for analyzing the economics of alternate IM methods and other processes without the prohibitive economic burden of trial-and-error innovation and process optimization. Cost variations are analyzed by setting up differing (1) performance requirements, (2) part design, (3) plastic selection, (4) hardware selection, and (5) testing, quality-control, and troubleshooting factors.

Figure 35 serves as a reminder that any action during IM (or any other process) is a balance between gains and losses. With a gain in one area "something" lost could influence product performance, cost, and other factors. Thus with people working smarter, using the follow-all-opportunities approach, analyzing failures or limitations, and innovating, targets can be expanded (Figure 36) and future product requirements can be met.

FUNDAMENTALS OF DESIGNING WITH PLASTICS AND REINFORCED PLASTICS

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A practical, easy approach to designing with plastics and reinforced plastics (RPs) is basically no different than designing with other materials such as steel, aluminum, titanium, copper, wood, and so forth. Each material has its respective advantages that require certain different design approaches. For example, with about 17,000 plastics available worldwide, one has to comprehend factors such as the range of their different properties, structural responses, product-performance characteristics, part shapes, available fabricating processes and their influence on product performances, and the influence of economics on design approaches.

Many different products have been designed and fabricated that range in weight and size from grams to many tons having simple to very complex shapes. Products take low to extremely high loads and operate in widely different environments.

With plastics, to a greater extent than the other materials, an opportunity exists to optimize design by focusing on a material's composition and orientation as well as its structural-member geometry. There are important interrelationships among shape, material selection, consolidation of parts, manufacturing selection, and other factors that provide low-cost, high-performance products. For the many applications that require only minimal mechanical performance, shaping through processing techniques can provide significant performance and cost advantages when using commodity plastics.

Figures 1 through 8 and Tables 1 and 2 provide a simplified flow-pattern guide to product design.

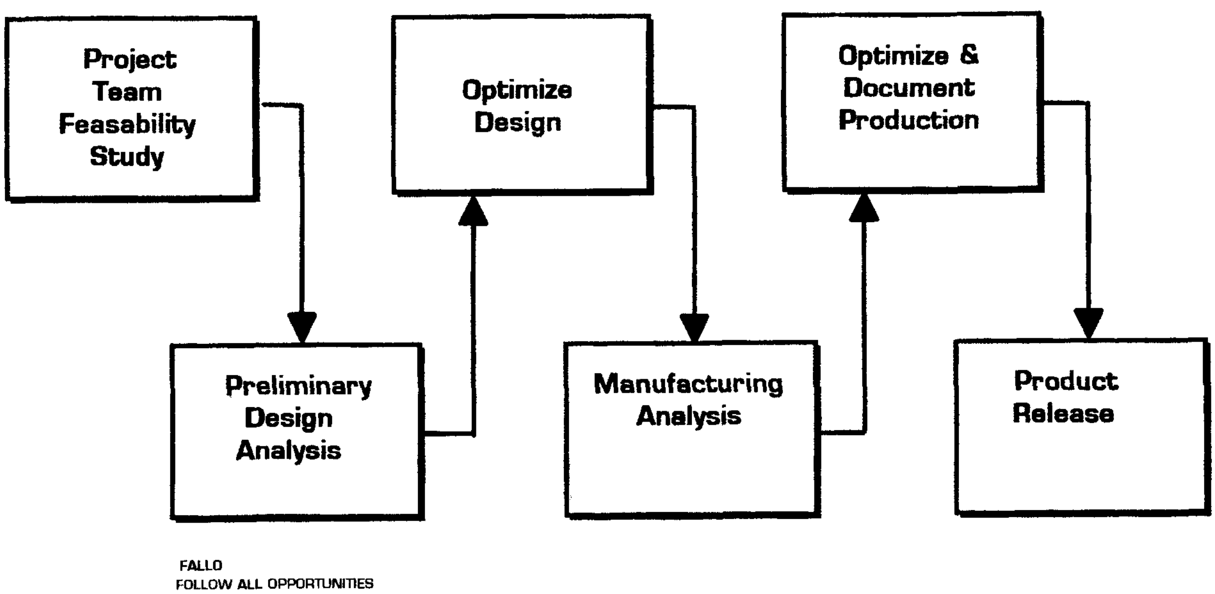


Fig. 1. Product Design Flow Pattern.

(All figures in this article are from the source: DVR, Injection Molding Division Newsletter, Society of Plastics Engineers.)

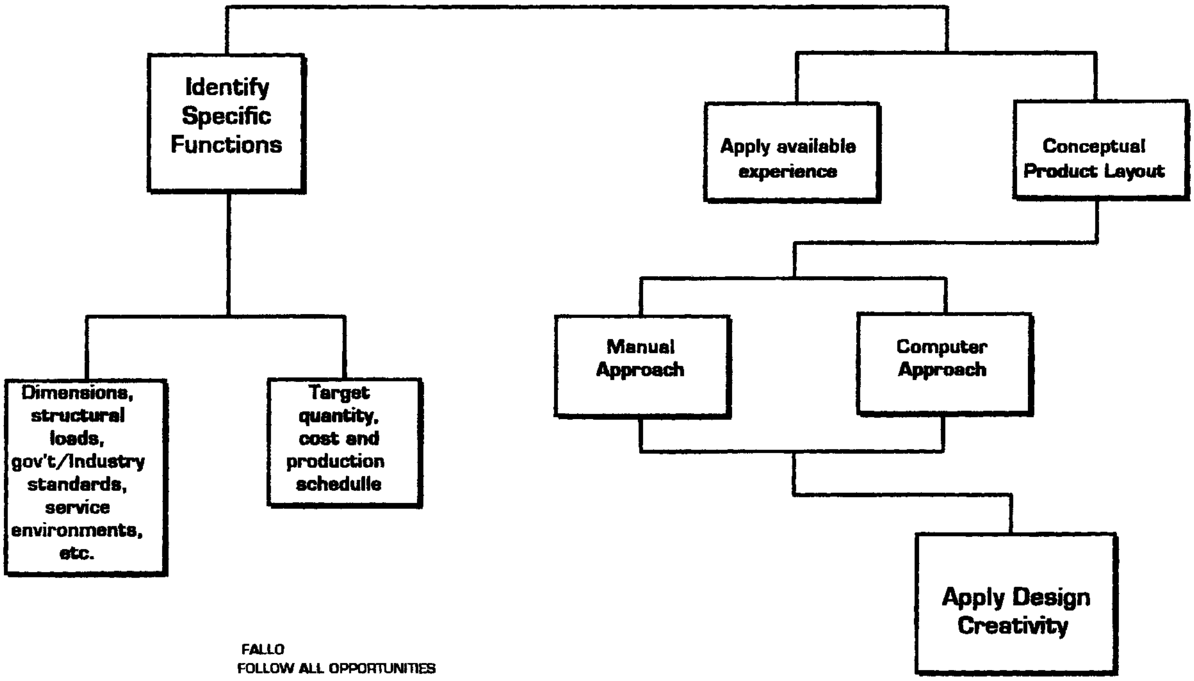


Fig. 2. Project Team Feasibility Study.

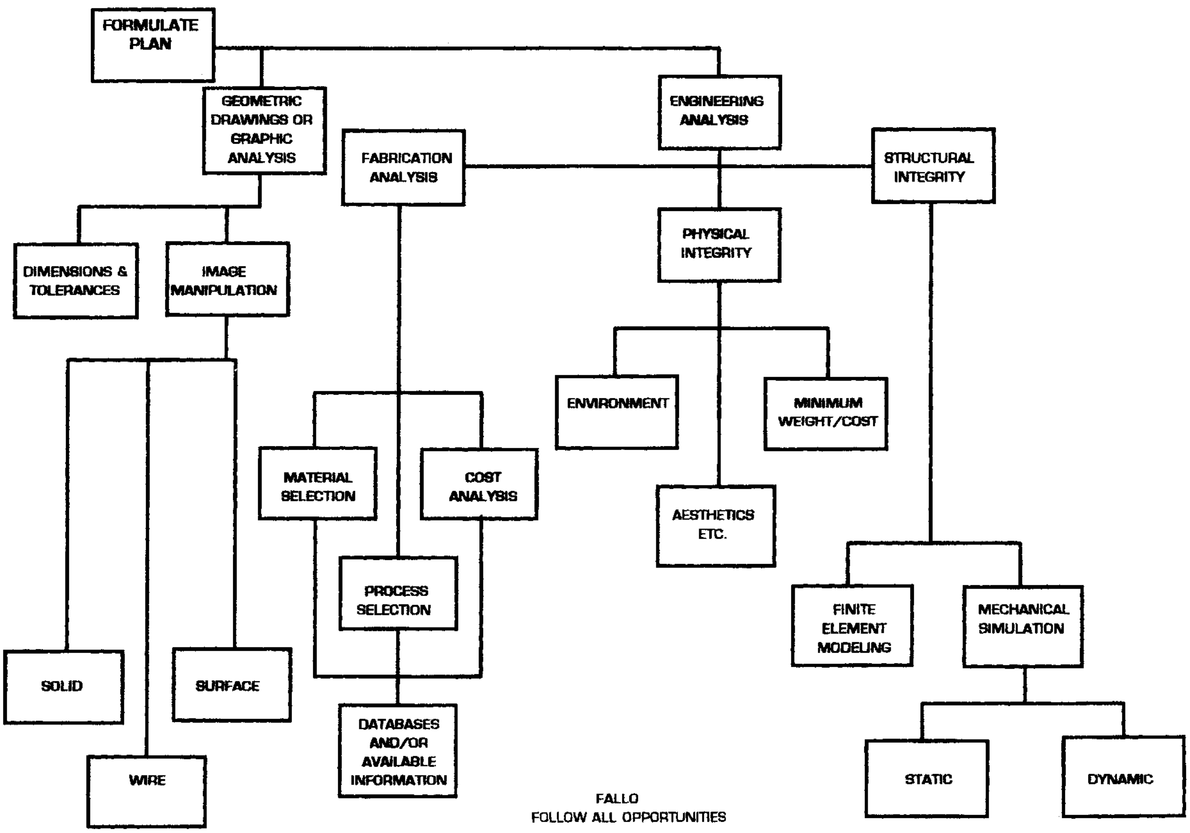


Fig. 3. Preliminary Design Analysis.

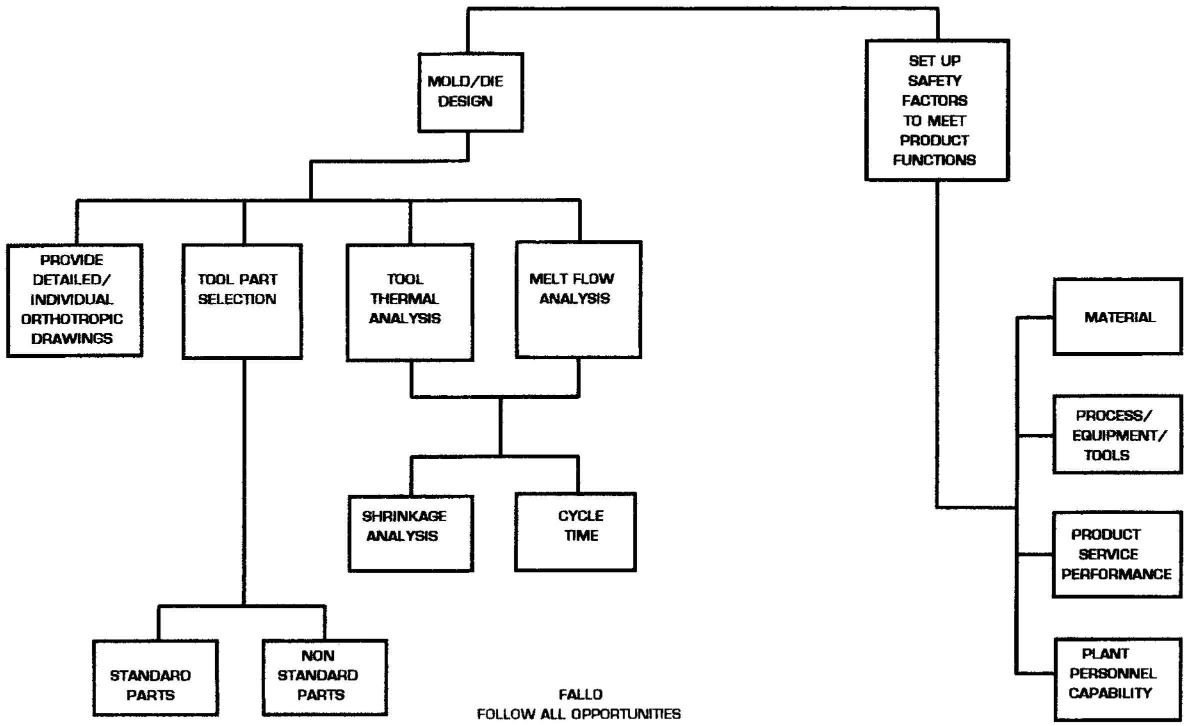
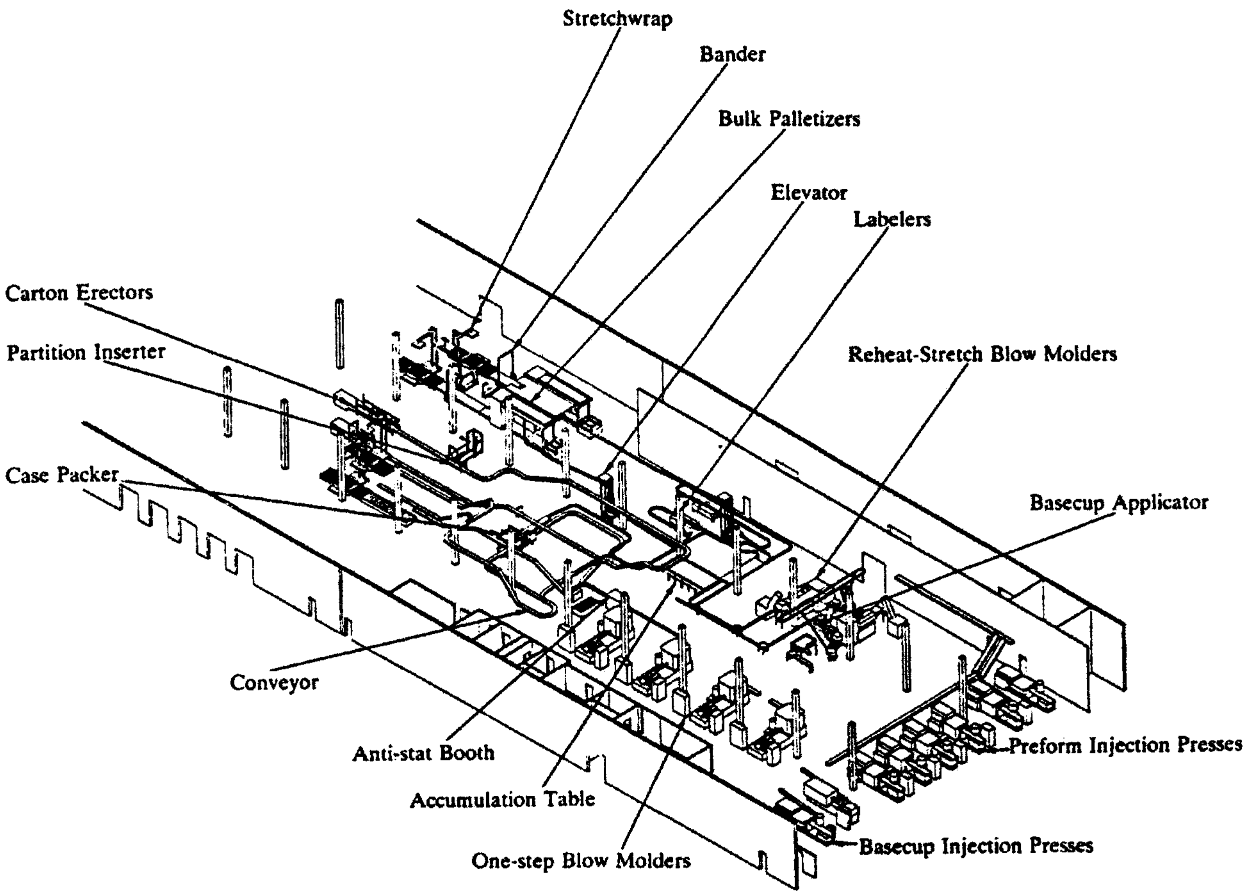


Fig. 4. Optimizing Design.



Example of injection molding production bottle blow molding plant

Fig. 5. Optimizing Plant Layout Design.

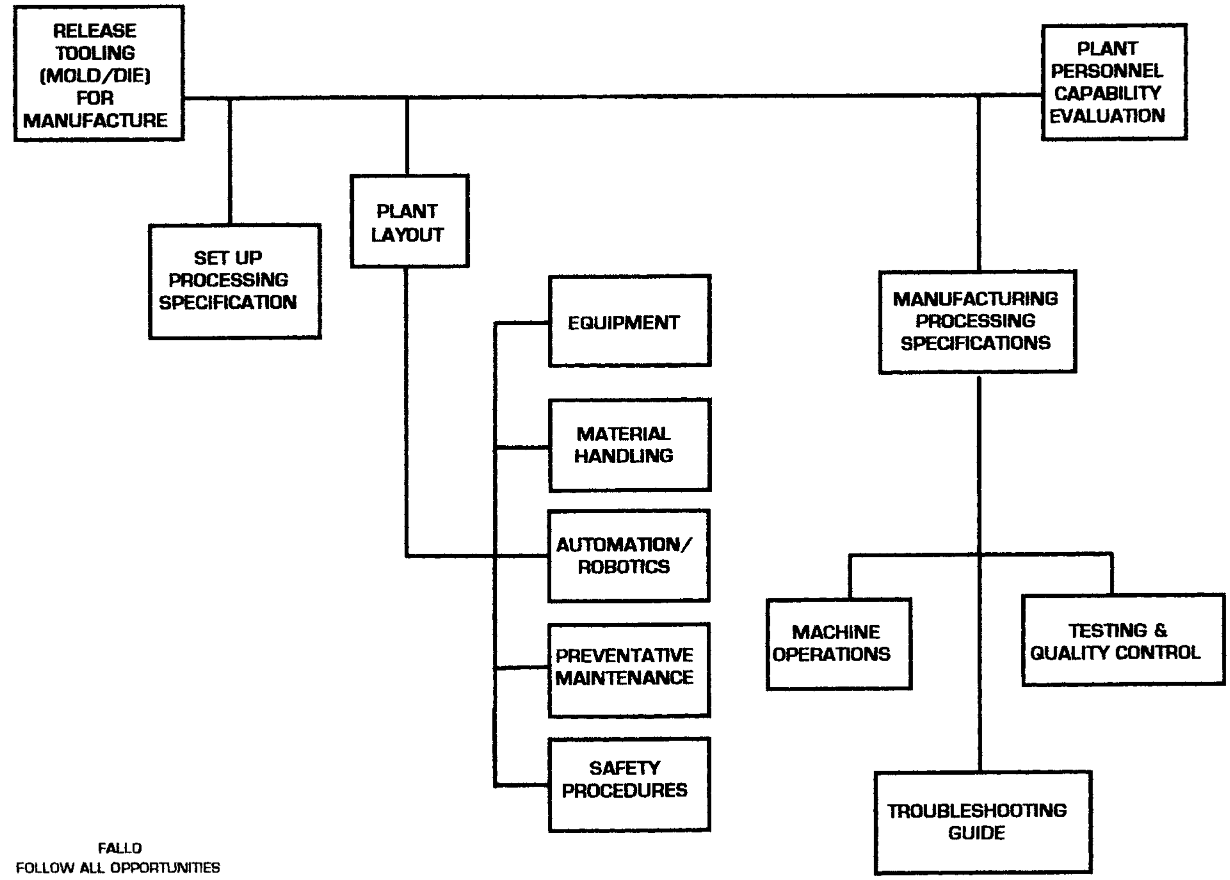


Fig. 6. Manufacturing Analysis.

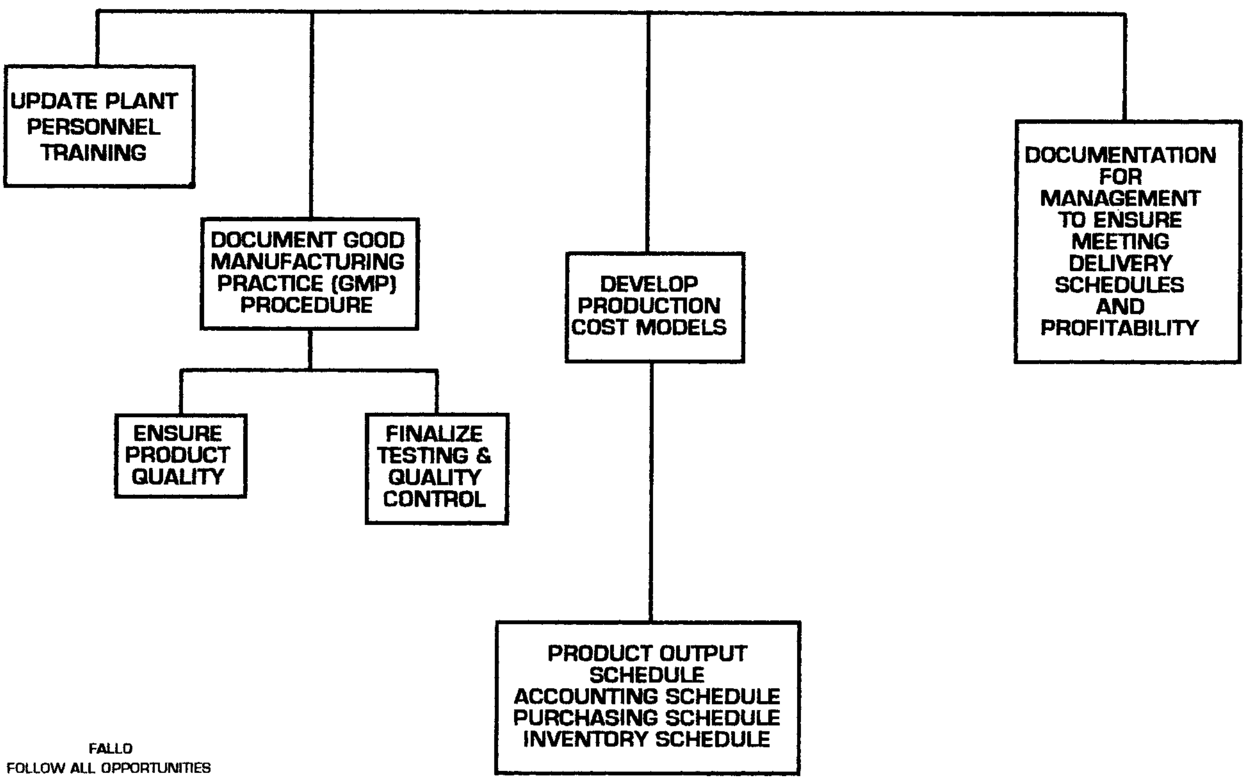


Fig. 7. Optimizing Document Reproduction.

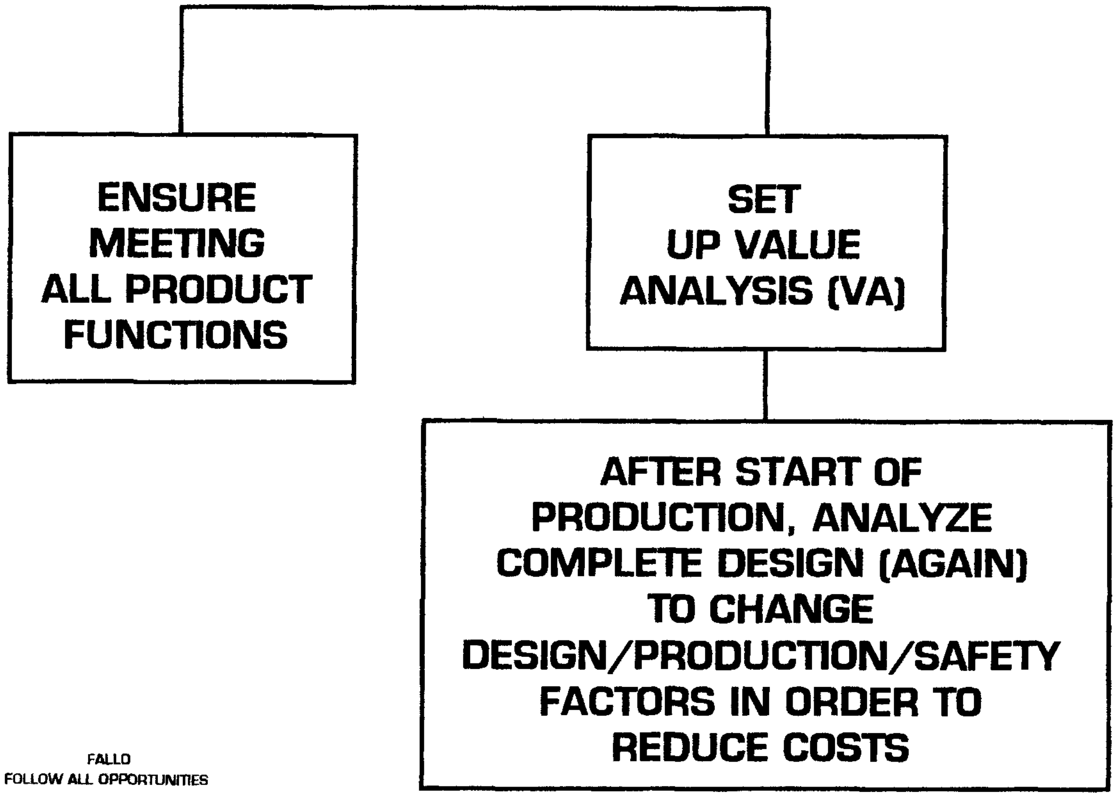


Fig. 8. Production Release.

Table 1. Glass-Reinforced Thermoplastic Compound Selector (LNP Engineering Plastics, Inc.).

G/R Resin Groups \ Design Criteria	Strength & Stiffness	Toughness	Short-Term Heat Resistance	Long-Term Heat Resistance	Environ-mental Resistance	Dimensional Accuracy In Molding	Dimensional Stability	Wear & Frictional Properties	Cost
Styrenics	**3**	**6**	**6**	**6**	**6**	**1**	**5**	**6**	**2**
ABS	2	1	1	1	1	3	2	3	3
SAN	1	2	2	2	2	1	1	1	2
Polystyrene	3	3	3	3	3	2	3	2	1
Olefins	**5**	**4**	**4**	**5**	**3**	**5**	**5**	**3**	**1**
Polyethylene	2	2	2	2	2	1	1	2	1
Polypropylene	1	1	1	1	1	1	1	1	2
Other Crystalline Resins	**1**	**1**	**2**	**4**	**4**	**4**	**4**	**2**	**3**
Nylons 6	2	2	2	2	5	1	4	3	1
Nylons 6/6	1	3	1	1	4	2	3	2	2
Nylons 6/10, 6/12	3	1	3	3	3	2	2	3	4
Polyester	4	4	2	1	2	2	1	4	1
Polyacetal	5	5	5	2	1	3	2	1	1
Arylates	**3**	**2**	**3**	**3**	**5**	**1**	**2**	**4**	**4**
Modified PPO	4	3	4	4	3	4	4	4	1
Polycarbonate	2	1	3	3	4	1	3	3	2
Polysulfone	2	2	2	2	2	2	2	1	3
Polyethersulfone	1	3	1	1	1	3	1	2	4
High Temp. Resins	**2**	**4**	**1**	**1**	**2**	**4**	**1**	**4**	**5**
PPS	1	2	2	2	1	1	2	2	1
Polyamide-imide	2	1	1	1	2	2	1	1	2
Fluorocarbons	**6**	**2**	**2**	**1**	**1**	**6**	**6**	**1**	**6**
FEP	2	1	2	1	1	2	2	1	2
ETFE	1	2	1	2	2	1	1	2	1

Ratings: 1-most desirable 6-least desirable. Large numbers indicate group classification, small numbers are for the specific resins within that group.

Strength & stiffness:- The ability to resist instantaneous applications of load while exhibiting a low level of strain. Materials which demonstrate a proportionality between stress and strain have been assigned better relative ratings.

Toughness:- The ability to withstand impacting at high strain rates.

Short-term heat resistance:- The ability to withstand exposure to elevated temperatures for a limited period of time without distortion.

Long-term heat resistance:- The ability to retain a high level of room-temperature mechanical properties after exposure to elevated temperature for a sustained period.

Environmental resistance:- The ability to withstand exposure to solvents and chemicals.

Dimensional accuracy in molding:- The ability to produce warp-free, high tolerance molded parts.

Dimensional stability:- The ability to maintain the molded dimensions after exposure to a broad range of temperatures and environments.

Wear and frictional properties:- The ability of the plastic to resist removal of material when run against a mating metal surface. The lower the frictional values, the better the relative rating.

Cost:- The relative cost per cubic inch.

Table 2. Impellor for Chemical Handling Pump. Design Criteria: Strength and Stiffness, Toughness, Short-Term and Long-Term Heat Resistance and Environmental Resistance.

Material Characteristics	Strength & Stiffness	Toughness	Short-Term Heat Resistance	Long-Term Heat Resistance	Environ-mental Resistance	Dimensional Accuracy in Molding	Dimensional Stability	Wear & Frictional Properties	Point Sub Total	Cost	Point Total
Design Criteria / G/R Resin Groups	X		X	X	X						
Styrenics ABS SAN Polystyrene	3		6	6	6				21	2	23
Olefins Polyethylene Polypropylene	5		4	5	3				17	1	18
Other Crystalline Resins Nylons 6 6/6 6/10, 6/12 Polyester Polyacetal	1		2	4	4				11	3	14
Arylates Modified PPO Polycarbonate Polysulfone Polyethersulfone	3		3	3	5				14	4	18
High Temp. Resins PPS Polyamide-imide	1 2 2		2 1 1	2 1 1	1 2 2				6 6 6	1 2 5	7 8 11
Fluorocarbons FEP ETFE	6	2	2	1	1				10	6	16

Comments: **"High Temp. Resins" clear choice throughout. Final selection would be PPS based on price advantages. If Heat Resistance had not been a factor, Olefins would have been the choice.**

A

abaca See **fiber, abaca.**

A-basis The value above which at least 99 percent of the population of values is expected to fall with a confidence of 95 percent. Also called *A-allowable*. See **B-basis; population confidence interval; S-basis; typical basis.**

A-B-C analysis An inventory classification system that characterizes inventory items according to usage, with the A category having the highest dollar usage, the B category the average usage, and the C category having the lowest dollar usage. See **cost; inventory; material handling; storage.**

A-B-C stages The various stages of cure when processing thermoset (TS) plastic that has been treated with a catalyst: A-stage is uncured, B-stage is partially cured, and C-stage is fully cured. Typical B-stage products are TS molding compounds and prepregs, which in turn are processed to produce C-stage fully cured plastic material products; they are relatively insoluble and infusible. See **phenolic plastic; postforming; prepreg; reinforced plastic prepreg; thermoforming material; thermoset plastic.**

abductive reasoning See **intelligence, artificial.**

aberration **1.** See **light aberration. 2.** The failure of an optical system to form an image of a point as a point, of a straight line as a straight line, or of an equal angle as an equal angle.

abherent A material applied to coatings and films as well as to molds and calender rolls to prevent or reduce adhesion to another surface. See **antiblocking agent; mold release agent.**

abhesive A material that resists adhesion. See **adhesion.**

ablation An orderly heat- and mass-transfer process in which a large amount of thermal energy is expended by superficial loss of surface region material. The heat input from the environment is absorbed, dissipated, blocked, and generated by numerous mechanisms. The energy-absorption processes take place automatically and simultaneously, serve to control the surface temperature, and greatly restrict the flow of heat into the substrate interior. See **carbonization; wear.**

ablative plastic A material that absorbs heat while part of it is being consumed by heat through a decomposition process that takes place near the surface exposed to the heat. An example is a carbon fiber-phenolic reinforced plastic on a space vehicle that is exposed to a temperature of 1,650°C (3,000°F) on reentry into the earth's atmosphere from outer space. See **atmosphere; coating, intumescent; endothermic; flame retardant; pyrolysis; temperature property of plastic.**

ABL bottle An internal-pressure vessel used to determine the quality and properties of the filament winding material in a vessel; named for the Allegheny Ballistic Laboratory. See **filament winding; test, NOL ring.**

abraid To roughen a surface by rubbing, scraping, or wearing away material. This action can prepare a surface for aesthetic, bonding, printing, etc. See **abrasive; chemical etching; surface treatment.**

abrasion **1.** The wearing away of some surface area through contact with another material. Abrasion is only one of many types of wear that vary depending on the type of material involved (elastomers, plastics, reinforced plastics) and the conditions of operation to which they are subjected, such as sliding or rolling, speed, temperature, stress, etc. See **adhesive abrasion; friction; mar resistance; wear. 2.** The loose fine particles and any relatively hard foreign matter that find their way between rubbing surfaces and that cause abrasion.

abrasion cleaning See **cleaning, abrasion.**

abrasion index A volume measurement of the abrasion resistance of a material relative to that of a standard under similar conditions.

abrasion resistance The ability of a material to withstand the removal of material from its surface due to contact with another surface as the result of mechanical action of a rubbing, scraping, or erosive nature (through sand, etc.). Abrasion is only one factor in wear. See **bearing; mold cavity coating; wear.**

abrasion test See **test, abrasion.**

abrasive A hard, mechanically resistant material that is used for grinding or cutting, and that consists essentially of particles. The abrading materials (aluminum oxide, silicon carbide, boron carbide, man-made diamond, flint, etc.) are bonded together usually with heat-resistant thermoset plastics such as phenolic and epoxy to form a wheel or abrasive bar, abrasive paper, fiber pads, wire mesh, brushes, etc. See **comminute; grinding; pumice.**

abscissas direction See **directional property, abscissas.**

ABS nylon alloy A thermoplastic alloy of acrylonitrile-butadiene-styrene plastic (ABS) and nylon (PA) with properties similar to ABS but with higher elongation at yield. See **acrylonitrile-butadiene-styrene plastic; nylon plastic.**

absolute density See **gravity, absolute.**

absolute humidity See **humidity, absolute.**

absolute specific gravity See **density and specific gravity.**

absolute temperature See **temperature, absolute zero.**

absolute viscosity See **viscosity, absolute.**
absolute zero temperature See **Kelvin scale; temperature, absolute zero.**
absorb To take up a substance in bulk.
absorbable technology See **medical absorbable technology.**
absorbance The common logarithm of the reciprocal of the transmittance of a pure solvent. Also called *absorbancy.* See **elute.**
absorbate A solid, liquid, or gas that is absorbed as molecules, atoms, or ions by such substances as certain plastics, charcoal, silica, etc.
absorbation, water Water contained within a material. See **test, water absorption; water absorption.**
absorbency The penetration of one substance into another.
absorber See **aerogel; molecule, chromophore; pollution, air; ultraviolet absorber and light stabilizer.**
absorptance See **luminous flux absorptance.**
absorption 1. The relation of the weight of a liquid (water or moisture, chemical, etc.) absorbed by a material (subjected to prescribed immersion procedures) to the weight of a dry material, expressed in percentage of change. See **desiccant; energy absorption; moisture absorption. 2.** The penetration into the mass of the substance by sound absorption. **3.** See **adsorption; desorption; infrared spectroscopy; permeability; pigment; sorbent; sorption; sound absorption; spectroscopy, absorption; swell.**
absorption, electrical See **dielectric absorption.**
absorption, isobar A graph showing how adsorption varies with a parameter such as temperature, while holding pressure constant.
absorption line A minute range of wavelength or frequency in the electromagnetic spectrum within which radiant energy is absorbed by the medium through which it is passing. See **energy, radiant.**
absorptivity Absorptance divided by the product of concentration of the substance and the sample path length.
ABS plastic See **acrylonitrile-butadiene-styrene plastic.**
accelerated aging Aging in a short time by artificial means to obtain an indication of how a material or product will behave under normal conditions over a prolonged period in service. See **aging, artificial; weathering, artificial.**
accelerated life test A method designed to approximate, in a short time, the deteriorating effect of normal, long-time plastic aging or machine aging service conditions. See **weatherability, accelerated.**
acceleration See **calculus.**
acceleration, gravity See **gravity acceleration.**
accelerator A chemical substance that accelerates chemical, photochemical, biochemical, etc. reaction during processing, such as cross-linking or degradation of plastics. Action is triggered or sustained by another substance, such as a curing agent or catalyst, or environmental condition, such as heat, radiation, or a microorganism. It can be used to hasten a chemical reaction with a catalyzed thermoplastic or thermoset plastic or to reduce the time required for a TS plastic to cure or harden. Often used in room-temperature cures. During processing, it undergoes a chemical change. Also called *cocatalyst* or *promoter.* See **activator; catalyst; hardener.**
accelerator, rubber A chemical that accelerates the rate of rubber vulcanization. See **zinc diethyl dithiocarbamate; zinc oxide.**
acceptable quality See **quality level, acceptable; sampling acceptable quality level.**
acceptable risk See **risk, acceptable.**
acceptance number Also called *quality acceptance number.* See **quality level, acceptable.**
acceptor 1. A chemical whose reaction rate with another chemical increases because the other substance undergoes another reaction. **2.** A species that accepts electrons, protons, or molecules such as dyes.
accessory element See **tracer.**
accordion fold See **fold, accordion.**
accounting See **business bookkeeping.**
accreditation See **laboratory accreditation.**
accumulator 1. A device for conserving energy in hydraulic systems of processing equipment. Oil is stored under pressure and used when required to boost oil pressure. **2.** An auxiliary ram device used to provide large amounts of plastic melts with fast-melt delivery in a fabricating machine (blow molding, injection molding, foam molding, etc.), resulting in fast molding cycles or output rates. For example, melt is stored or accumulated in a cylinder until the next melt is required for the BM extruder parison (up to at least 400 lb capacity) or IM shot. See **blow molding, extruder (intermittent); extruder; injection molding, foamed low pressure. 3.** A device for the temporary storage or accumulation of film on an extrusion or calender line, where it is called a festoon. See **festoon.**
accumulator adapter A mechanical structure containing the flow passage connecting an accumulator to a device such as a plasticator. See **plasticator.**
accumulator, blow molding See **blow molding, extruder (intermittent versus continuous).**
accumulator, injection molding See **injection molding machine, two-stage.**
accuracy A clear understanding of information (data, terms, etc.) that helps ensure reliable conversion of that information. See **design accuracy; deviation, standard measurement; repeatability; sensor, dynamic accuracy.**
acetaldehyde A colorless, pungent, flammable liquid of importance in the synthesis of organic compounds. It reacts with polyvinyl alcohol to form polyvinyl acetate and with cresol or phenol to form thermoset plastics. See **Wacker process.**
acetal plastic One of the strongest and stiffest members in the family of thermoplastics. Also called *polyacetal,*

POM, polyoxymethylene, or *polyphosphazene plastic.* This highly, opaque white, crystalline engineering thermoplastic has a high-impact strength, stiffness, resiliency, toughness (rain erosion resistant, etc.), and yield stress; low friction coefficient; low gas and vapor permeability; exceptional dimensional stability and dielectric properties; high fatigue strength; and good retention of properties at elevated temperature. These plastics are denser than nylon but share many properties with nylon. They have relatively low water absorption. The homopolymers have a higher heat-deflection temperature but lower continuous-use temperature than copolymers. All acetals have poor resistance to acids, and homopolymers also show poor resistance to alkalies. See **ether-oxide plastic; polymer, homo-.**

acetate A compound derived from acetic acid. The name commonly is used for the cellulose acetate group of plastics. See **cellulose acetate plastic.**

acetone A volatile, colorless, highly flammable liquid that is miscible with water, has an autoignition temperature of 537°C (1,000°F), mixes readily with water and some other solvents, and is moderately toxic. Also called *ketone.* It dissolves in most TPs and some TSs and is used as an organic synthesis intermediate, a reagent, an antioxidant, a solvent in paints and acetate fiber spinning, etc. See **ketone.**

acetylene An intermediate in the manufacture of many of the large-volume monomers used in plastics, such as polyvinyl chloride, chloroprene, acrylonitrile, vinyl acetate, and acrylic ester. It has a triple bond between two carbon atoms and can be made from calcium carbide and water. See **atom bond, multiple; calcium carbide; chemistry, acetylene; monomer.**

acid 1. Any of a class of chemical compounds whose aqueous solutions turn litmus paper red, react with and dissolve certain metals to form salts, and react with bases to form salts. **2.** It is a compound capable of transferring a hydrogen ion in solution. See **dibasic. 3.** A substance that ionizes in solution to yield the positive ion of the solvent. **4.** A molecule or ion that combines with another molecule or ion by forming a covalent bond with two electrons from the other species. **5.** See **zirconium.**

acid-acceptor A compound that acts as a stabilizer by chemically combining with an acid that may be initially present in minute quantities in a plastic or that may be formed by the decomposition of the plastic.

acid-base pair, conjugate A Bronsted-Lowry acid and the base formed after the acid has lost H^+ ion. See **Bronsted-Lowry acid.**

acid gas A byproduct of the incomplete combustion of solid waste and fossil fuels with a pH value of less than 6.5, most commonly sulfur dioxide, hydrogen chloride, and nitrogen oxide. See **pH.**

acid ionization constant The equilibrium constant for ionization of an acid. See **ionization.**

acid, organic See **organic acid.**

acid rain Any form of precipitation (wet deposition) having a pH of 5.6 or less. Also called *acid precipitation.* Its most deleterious components are sulfur dioxide and oxides of nitrogen either emitted as stack gases in highly industrialized areas or as volcanic activity. See **pH; precipitate; vinyl composition tile; water pollution.**

acid reaction See **chemical reaction, acid.**

acid value A measure of the free acid content of a substance. It is normally expressed as the number of milligrams of potassium hydroxide required to neutralize one gram of the substance using phenolthaline as an indicator.

acknowledgment See **government contract directory; legal matter: acknowledgment; legal matter: product liability law; legal matter: shop-right.**

acoustical board Low-density, sound-absorbing insulation. See **sound absorption.**

acoustical sensor See **piezoelectric plastic.**

acoustic emission testing See **test, nondestructive acoustic emission.**

acoustic holography See **test, nondestructive acoustic holography.**

acoustic impedance See **mathematical acoustic impedance.**

Acrobot See **printing, Acrobot.**

acrolein plastic The simplest unsaturated aliphatic aldehyde. These thermoset plastics are colorless but become colored above 170°C (338°F) and sinter at 220°C (428°F) without melting. Their physical and chemical properties depend more on conditions of preparation than is normally the case with other plastics.

acrylamide copolymer plastic A thermoset plastic formed using acrylamide with other plastics such as acrylic plastic to form tough transparent materials.

acrylamide plastic A specialty plastic with limited use in water treatment, mining, and paper manufacture.

acrylate plastic An acrylic acid or ester plastic used in paints, adhesives, other plastics, and sizings and finishes in paper and textiles. It is a thermoplastic made by the polymerization of an acrylic compound such as PMMA. See **casting acrylic sheet.**

acrylate styrene acrylonitrile plastic A hygroscopic acrylic rubber-modified thermoplastic with high outdoor weatherability. Also called *ASA acrylonitrile styrene acrylate plastic,* or *acrylic styrene acrylonitrile plastic.* It offers high gloss, good heat and chemical resistance, excellent toughness and rigidity, high-impact strength, and good antistatic behavior. See **plastic, hygroscopic.**

acrylate-styrene-acrylonitrile plastic PVC alloy A combination that extends performances of individual plastics.

acrylglass plastic An acrylic plastic glazing material best known for its uses in the glazing of airplanes. See **glazing.**

acrylic acid With esters, a versatile series of monomers for providing performance characteristics to thousands of polymer formulations. They are flammable, reactive, volatile liquids based on unsaturated carboxyl structure. Using varying percentages permits thousands of formulations for latex and solution copolymer plastics and cross-linked plastic systems. Their performance characteristics impart varying degrees of tackiness, durability, hardness, glass transition temperatures, etc. See **monomer.**

acrylic elastomer A family of thermoplastic elastomers whose rubbery products contain a predominant amount of an acrylic ester, such as ethyl acrylate or butyl acrylate.

acrylic emulsion A water-based thermoplastic latex made from acrylic plastic and used in coatings and adhesives. See **adhesive; coating; latex.**

acrylic ester An ester of acrylic acid or of a structural derivative of acrylic acid, such as methyl methacrylate plastic. See **acrylic acid.**

acrylic ethylene rubber See **ethylene acrylic elastomer.**

acrylic fiber See **fiber, acrylic.**

acrylic plastic A family of amorphous thermoplastics that are comprised of homopolymers and copolymers of alkyd methylacrylates. Also called *polymethyl methacrylate plastic, PMMA, polyacrylate,* or *acrylate plastic.* The most common monomers used are methyl and ethyl methylacrylates. They offer excellent optical clarity (92% light transmission), excellent resistance to weathering with particular resistance to sunlight, surface hardness, good chemical resistance, rigidity, excellent dimensional stability, low mold shrinkage, good impact strength and electrical properties, nontoxicity, and tastelessness. Powders can be injection and compression molded, extruded, etc. Liquids can be cast into sheets, lenses, and rods. Approximately 30wt% of production is used for coatings and paints, 13% construction, 11% plastic products, 8% textiles, and 38% in other markets. In many markets, acrylics compete directly with polycarbonate plastics that have similar optical properties and better impact resistance but that are more susceptible to ultraviolet degradation and more expensive than acrylics. See **casting acrylic sheet; hydrogel market; transparent plastic.**

Acrylite The CYRO trade name for its family of acrylic plastic sheets.

acryloid plastic An early name for polymethyl acrylates in solution for use as adhesives and coatings or methacrylate plastics used as lubricants or oil viscosity modifiers.

acrylonitrile A colorless liquid compound used in the manufacture of acrylic elastomers and fibers. Also called *vinyl-cyanide* or *AN.* A monomer with the structure CH_2:CHCN useful in copolymers. Its copolymer with butadiene is nitrile rubber and several copolymers with styrene exist that are tougher than conventional polystyrene plastics. It is also used as a synthetic fiber and as a chemical intermediate. AN provides good gas barrier, chemical resistance, as well as low taste and odor transfer.

acrylonitrile-butadiene rubber A copolymer with 20 to 50 percent of acrylonitrile that was developed as a general-purpose, oil-resistant rubber. Also called *nitrile rubber* or *NBR.* Its resistance to oils, fuels, and solvents is superior to that of polychloroprene (CR). Heat aging is rather good, and abrasion resistance is high.

acrylonitrile-butadiene-styrene (ABS) plastic An amorphous engineering thermoplastic elastomer-modified styrene. It is a terpolymer comprised of a mixture of styrene-acrylonitrile (SAN) copolymer and SAN-grafted butadiene rubber. The ratios of the three monomers can vary considerably, yielding a large family of plastics with special emphasis on clarity and heat-warpage resistance. As an example, small rubber particles improve gloss, while larger particles (up to several microns) tend to improve toughness while lowering gloss. ABS is often considered to be a modified PS since its properties resemble PS, but its improvements, such as its impact strength, are much higher. ABSs are very tough but not brittle, hard, and rigid. These chemically resistant materials offer low water absorption, good dimensional stability, good electrical properties, and high abrasion resistance, and some grades are easily electroplated. See **nail.**

acrylonitrile-butadiene-styrene (ABS) plastic transparent A transparent product made by matching the refractive indices of the elastomer and the SAN phases, usually by incorporating methyl methacrylate.

acrylonitrile-chlorinated polyethylene-styrene (ACS) copolymer A copolymer with properties similar to ABS, except that it is more resistant to embrittlement due to oxidative degradation and has better fire resistance.

acrylonitrile copolymer plastic **1.** A class of plastics including ASA, ABS, SAN, and nitrile rubber. This term is often used to denote high nitrile barrier plastics. These plastics are copolymerizations of acrylonitrile that have been impact modified with acrylic ester. They have good gas barriers, good taste, and odor retention properties, moderately high tensile and impact properties (when rubber modified or oriented), and chemical resistance. **2.** An oil-resistant elastomer made by the polymerization of acrylonitrile with compounds such as butadiene or acrylic acid.

acrylonitrile-ethylene-styrene (AES) plastic An amorphous, opaque, terpolymer produced by suspension, emulsion, or continuous mass polymerization. Sometimes called *olefin modified acrylonitrile-styrene* (*OAS*), *styrene-acrylonitrile plastic* (*SAN*), or *acrylic-styrene-acrylonitrile* (*ASA*). Properties are similar to ABS, with the addition of weatherability and ultraviolet protection for outdoor use.

acrylonitrile plastic A crystalline thermoplastic useful in copolymers. Its copolymer with butadiene is nitrile rubber (AN), which is tougher than polystyrene. It is also used as a synthetic fiber. See **Coca-Cola bottle.**

acrylonitrile rubber See **nitrile rubber.**

acrylonitrile-styrene plastic A high nitrile plastic: styrene-AN or other monomer AN copolymer with a high AN content of about 70 to 80wt%. Such copolymers have a very low permeability to gases, including carbon dioxide, and liquids, good chemical resistance, etc. Thus, they are called barrier plastics. This was the first plastic used to produce stretched blow-molded carbonated beverage bottles. See **blow molding, stretched; Coca-Cola bottle.**

activated complex See **molecule, activated complex.**

activated diffusion See **permeability.**

activation See **chemical etching activation; radiation activation.**

activation energy See **energy activation.**

activator A compounding material used in small proportions to increase the effectiveness of an accelerator. Both organic and inorganic types may be used; and most require both zinc oxide and a fatty acid such as stearic acid to develop optimum final properties. They are usually added at the start of compounding, to eliminate the potential difficulty in dispersing them evenly throughout the mixed compound. See **accelerator.**

actual versus theoretical property See **plastic data, theoretical versus actual property.**

actuating function See **plastic, smart.**

adapter A mechanism or device for attaching nonmating parts. Examples of this mechanical reducing mechanism include a plasticator barrel to nozzle or die and a thermal insulator from the nozzle to the barrel for temperature control.

adapter system Everything located between the screw and the tool (mold or die), sometimes including components such as a screen pack or static mixer. The adapter system's streamlined design must ensure that flow channels do not contain sudden changes in cross-section, surface interruptions (caused by mismatched assembly joints or damage) or other dead spots because areas of stagnation can give rise to localized plastic degradation and the subsequent release of particles of degraded plastic into the melt stream. Adequately sized heaters must be provided for the adapter, since it is generally a large piece of metal. The temperature of the adapter and head must be controlled separately, since they usually differ greatly in size and energy requirements. See **blow molding; extruder; injection molding.**

adaptive control See **control, adaptive.**

addition polymerization See **polymerization, addition.**

additive A substance compounded into a plastic to modify its characteristics. Additives are physically dispersed in a plastic matrix without significantly affecting the molecular structure of the thermoplastic. In thermoset plastic, additives such as cross-linkings, catalysts, and other agents do affect structure. Additives are normally classified according to their specific functions rather than their chemical composition. Some additives have broad applications and are adaptable to many TPs and TS plastics, and others are used exclusively with specific plastics. The highest-volume additives are modifiers, followed by property extenders and processing aids. Of the plastics using additives, polyvinyl chloride is the major outlet for additives, followed by polyolefins and other plastics. The pace of development in additives continues unabated.

Additive classifications include those that (1) assist processing (processing stabilizers, processing aids and flow promoters, internal and/or external lubricants, thixotropic agents), (2) modify the bulk mechanical properties (plasticizers or flexibilizers, reinforcing agents, toughening agents), (3) reduce formulation costs (diluents and extenders, particle fillers), (4) modify surface properties (antistatic agents, slip additives, anti-wear additives, anti-block additives, adhesion promoters), (5) modify optical properties (pigments and dyes, nucleating agents), (6) perform antiaging tasks (antioxidants, ultraviolet stabilizers, fungicides), and (7) have various other applications (blowing agents, flame retardants).

There is no one ideal additive since each end use calls for a particular set of characteristics, including diverging properties. Improvements in one property can lead to deterioration in others, and the effectiveness of compounding additives depends on correctly incorporating them into the plastic matrix. The compatibility and diffusibility of additives are normally assessed from experience or by trial and error, using solution thermodynamics to determine potential compatibility. Additive theories for preliminary concepts meet specific performances. **See antiblocking agent; binder; carbon black; carnauba wax; chemical composition and plastic property; coconut shell; coke dust; compounding; dopant; filler; filler versus unfilled compound; macerate filler; migration and additive; pigment, inert; reinforcement; shell flour; stabilizer; thermoplastic; thermoset plastic; vermiculite; wax.**

additive and flame retardant See **phosphorous base flame retardant.**

additive and migration See **migration and additive.**

additive and performance See **test and classification.**

additive, biodegradable See **biodegradable versus photodegradable.**

additive chain extender An additive for certain plastics, such as castable polyurethane elastomers, that provides lower shrinkage, improves tensile strength, lowers compression set, and provides better mold release. See **extender.**

additive characterization See **spectroscopy, Fourier's transfer infrared.**

additive clarifier An additive that increases the transparency of a plastic. See **adhesive, isinglass.**

additive concentrate See **concentrate; pellet, micro-.**

additive, emulsifier See **emulsifying agent.**

additive, environmental friendly See **environmentally friendly additive.**

additive, flame retardant See **flame retardant.**

additive, impact modifier See **impact modifier.**

additive, inert A material, such as a filler, that is added to a plastic compound, may alter the properties of the fabricated part, but does not react chemically with any constituents of the compound. See **inert.**

additive, liquid A liquid material added to a plastic compound via pump dosing. Its disadvantages include spilling, screw slipping, longer equipment cleaning time, and capital investments for equipment for separate dosing. However, porous bead carriers used for liquid additives provide easy dosing by simulating solid additive actions. For example, nonhygroscopic beads act like sponges to absorb antistats, mold release agents, antioxidants, lubricants, fragrances, silanes, chain extenders, etc. See **fiberglass binder/sizing coupling agent.**

additive, lubricant See **lubricant.**

additive, photodegradable See **biodegradable versus photodegradable.**

additive, slip An additive modifier that acts as an internal lubricant by exuding to the surface of the plastic during and immediately after processing and thereby providing the necessary lubricity to reduce or eliminate coefficient of friction in molded parts, film, etc. products. See **antiblocking agent; antislip agent; lubricant; packaging, grocery bag; sweating.**

additive, surface modifying A material used to modify surface (or intersurface) properties in a desirable manner. Examples include external and internal mold release agents, slip agents, antistatic agents, and antifogging agents. See **mold release agent; surfacing.**

address See **computer address.**

adduct See **chemical adduct.**

adhere To cause two surfaces to be held together by an adhesive.

adherend A surface to which an adhesive adheres. See **curling.**

adherent A body (surface) held to another body (surface), usually by an adhesive or solvent.

adherometer An instrument that measures the force required to strip a coating from a base surface. See **adhesive peel strength.**

adhesion A state in which two surfaces are held together by interface forces. Adhesion may be by molecular attraction, mechanical, electrostatic, or solvent, depending on whether it results from interlocking action, from the attraction of electrical charges, from valence forces, or from solvent action, respectively. Also referred to as cementing, adhesive action, and bonding (however encompasses more than adhesive bonding). The methods or processes used include solvent welding, ultrasonic welding, mixing of reactive components, heat curing, moisture curing, light curing, and surface activation. See **adhesive; bonding; cohesion; molecular adhesion.**

adhesion, mechanical Adhesion between surfaces in which the adhesive holds the parts together by an interlocking action.

adhesion promoter A coating applied to a substrate prior to adhesive application to improve adhesion. Also called *primer.* See **primer.**

adhesive A substance made principally from thermoplastic and thermoset plastics (also vegetable, animal byproducts, silicates, etc.) and when applied as an intermediate is capable of holding material together by surface attachment. Advances in the use of TP and TS plastic adhesives have made possible the adhesive bonding of structural and nonstructural parts in appliances, automobile, aircraft, medical devices, and so on. Adhesives with strengths higher than some metals are used (epoxy, etc.). The best adhesive for an application depends on processing considerations and performance requirements. See **adhesion; bonding; joining-and-bonding method; phenolic cement; plasma arc treatment; seal; staking; transcrystalline growth; welding; wetting agent.**

adhesive abrasion A surface preparation in which the part surface is mechanically abraded, usually in the presence of a liquid adhesive. See **abrasion.**

adhesive, acrylic emulsion See **acrylic emulsion.**

adhesive, aerobic An adhesive that requires air or oxygen to cure.

adhesive, anaerobic An adhesive that cures only in the absence of air after being confined between assembled parts.

adhesive, antimicrobial See **biocide.**

adhesive assembly The fabricating of the finished products with adhesives as differentiated from producing sheet materials with adhesives.

adhesive assembly time The time between spreading an adhesive and applying pressure. See **adhesive working time.**

adhesive binder See **binder; wood composition board.**

adhesive bite The ability of an adhesive to penetrate or dissolve the uppermost portions of the adherents. See **chemical etching; chromic acid etching.**

adhesive, bond breaker See **joining, bond breaker.**

adhesive bond improvement See **surface treatment.**

adhesive bonding surface See **satinizing.**

adhesive bonding to polyethylene or fluoroplastic See **surface CASING.**

adhesive bond line thickness See **microsphere.**

adhesive cement See **adhesive solvent cement; phenolic cement.**

adhesive, chemical bonding See **adhesive, solvent.**

adhesive coating, LOX compatibility See **polyarylene ether phosphine oxide plastic.**

adhesive coating method See **coating; coating, kiss-roll.**

adhesive cohesion The ability of a single substance to adhere to itself. See **cohesion.**

adhesive cohesive failure Failure occurring primarily in an adhesive layer. See **failure.**

adhesive cohesive strength The intrinsic strength of an adhesive. See **adhesive strength; strength.**

adhesive, cold-setting An adhesive capable of hardening at or below room temperature in the presence of a hardener. See **hardener; press, cold.**

adhesive, contact **1.** An adhesive that is apparently dry to the touch and that adheres to itself on contact with little or no pressure. Also called *impact adhesive.* **2.** An adhesive that, when applied to both adherends and allowed to dry, develops a bond when the adherends are brought together without sustained pressure. **3.** An adhesive that, for satisfactory bonding, requires that the surfaces to be joined to be a specific distance apart, such as 0.1 mm.

adhesive contact angle The angle formed by a droplet, usually water, in contact with a solid surface, measured from within the droplet. Applicable in determining degree of adhesive bonding or laminating based on wettability of the surface. A contact angle of zero implies complete wetting, an angle of 180° shows absolute nonwetting, and intermediate angles correspond to various degrees of incomplete wetting.

adhesive contact cement A mixture of elastomeric rubber and organic solvents that are cured on evaporation of the solvent. A coating is applied to both bonding surfaces, an aggressive tack develops within several minutes, and adhesive bonding then joins the surfaces (cement-cement).

adhesive, corrosive An adhesive that attacks the adherent surface due to chemically reactive materials in the adhesive. See **adhesive, solvent.**

adhesive, cyanoacrylate A highly reactive class of adhesives that cure rapidly at room temperature with a trace of moisture as its catalyst to form high-strength bonds with plastics, metals, etc.

adhesive, disbonded **1.** An area of a bond interface between two adherents in which an adhesive failure or separation has occurred. **2.** Colloquially, an area of separation between two laminae in the finished laminate. In this case the preferred term is *delamination.* See **laminate.**

adhesive dry strength The strength determined immediately after drying under specific conditions or after a period of conditioning. See **strength.**

adhesive, edge joining An adhesive used to bond together strips such as veneer by their edges in the formation of larger sheets. See **wood veneer.**

adhesive, electromagnetic A metallic preform that is placed in the joint area to convert electromagnetic energy into electric heat for thermoplastics fusion bonding. See **welding, fusion.**

adhesive, environmental See **environmentally acceptable coating, ink, and adhesive.**

adhesive failure The separation of two bonded surfaces that occurs within the bonding material. Failure occurs when the adhesive strength of a bonding material is greater than the cohesion strength. See **failure analysis.**

adhesive filler, anticrazing See **fiberglass milled.**

adhesive film A plastic adhesive usually in the form of a thin dry film (with or without a substrate such as paper, glass, plastic film, aluminum foil, etc.), used under heat and pressure as an interleaf in the production of adhesives, laminated products, etc.

adhesive, flame treat surface See **flame treating.**

adhesive gap filling An adhesive subject to reduced shrinkage after curing that can be used as a sealant. See **sealant.**

adhesive gluten A tough, rubbery, gray-brown protein substance of wheat flour that gives cohesiveness and is used in the production of adhesives and amino-acid production.

adhesive, heat-active A dry adhesive that is rendered tacky or fluid by the application of heat, or heat and pressure, to the assembly.

adhesive heat cure A relatively simple curing process that is easily controlled by maintaining consistent cure times and temperature profiles.

adhesive, heat-sealing A thermoplastic film adhesive that is melted between two adherend surfaces by heat application to one or both of the surfaces.

adhesive, hot-melt An adhesive applied in a molten state that forms a bond after cooling to a solid state. It acquires adhesive strength through cooling, unlike adhesives that achieve strength through solvent evaporation or chemical cure.

adhesive, hot-setting An adhesive that requires a temperature at or above 100°C (212°F).

adhesive, iodine treatment In adhesive bonding, a surface preparation technique in which the surface crystallinity of the plastic is changed from the alpha form, in which N-H groups are parallel to the surface, to the beta form, in which the N-H functional groups are perpendicular to the surface. Commonly used for nylons, iodine treatment increases the reactivity of the surface but is not believed to provide sites for mechanical interlocking.

adhesive, isinglass A white, tasteless gelatin derived from the bladder of fishes, usually the sturgeon. It is used as an adhesive and clarifying agent. See **additive clarifier.**

adhesive joint See **joining-and-bonding method.**

adhesive, lacquer type solvent See **lacquer; solvent.**

adhesive line The adhesive layer between two adherends. See **adherend; microsphere.**

adhesive, mechanical Adhesion between surfaces in which the adhesive holds the parts together by interlocking action.

adhesive, metal-to-plastic See **metal adsorption calorimetry; metal-to-plastic bond.**

adhesive, moisture cure An adhesive that polymerizes when moisture from the atmosphere diffuses into the appropriate adhesive.

adhesiveness The property defined by the adhesion stress $A = F/S$, where F is the perpendicular force to the adhesive line and S its surface area expressed in kg/cm^2 (lb/in.^{2}).

adhesive, nontacky See **fastener, mechanical non-.**

adhesive, nonwarp An adhesive system that does not distend, curl, or shrink.

adhesive, one-part An adhesive that does not require a separate hardener or catalyst for bonding to occur. Used in UV curing, emulsions, and solvents and can be water or moisture activated. See **adhesive, two-part; ultraviolet radiation.**

adhesive overlap A simple adhesive joint in which the surface of one adherend extends past the leading edge of another.

adhesive peel strength **1.** Adhesive bond strength obtained by a stress applied in a peeling mode. **2.** Force or peel strength required to remove a material, such as a pressure-sensitive label (adhesive bonded label), at a specified angle and speed. See **adherometer; bond strength; reinforced plastic peel ply; sandwich peel torque.**

adhesive penetration The amount of adhesive that seeps into the components of the joint or the material.

adhesive, plasma treatment See **plasma treatment.**

adhesive, plastic See **pentadiene plastic; plastic material selection.**

adhesive, plastic-to-metal See **metal adsorption calorimetry; metal-to-plastic bond.**

adhesive, plywood An adhesive suitable for bonding wood veneer together in the manufacture of plywood (nonwaterproof or waterproof grades). Phenolic and urea plastics are usually used. See **plywood; wood composition board.**

adhesive polarity **1.** The relative surface charge of the material resulting from the molecular structure of the adherend surface. See **molecular structure; polarity adhesive, polyurethane. 2.** One- or two-part adhesives that cure by a polymerization reaction to form temperature resistant bonds that can be both rigid and flexible. See **polyurethane plastic.**

adhesive, polyvinyl acetate (PVA) A thermoplastic that is unlike a thermoset plastic because it is not as strong. The most universally sold all-purpose adhesive: the common white and popular glue uses PVA, and white glues sold for children are watered-down versions of PVA. See **polyvinyl acetate plastic.**

adhesive, pressure-sensitive An adhesive that requires slight applied pressure on the parts for bonding to occur. It usually is composed of a rubbery elastomer and modified tackifier, which are applied to the parts as solvent-based adhesives or hot melts, highly thixotropic, and curing is instantaneous. See **decal; label, adhesive-bonded; polyvinyl ethyl ether plastic.**

adhesive promoter A coating applied to a substrate before it is coated with an adhesive to improve the adhesion of the plastic. Also called *adhesive primer.* See **primer.**

adhesive, proteinaceous An adhesive with a protein base, such as animal glue, casein, soya, etc. See **protein.**

adhesive, reactive-component Two-part systems that generally are made up of a base plastic (such as epoxy) and a catalyst. When mixed, the adhesive starts to polymerize, forming a thermoset plastic. Reactive components of the adhesive are kept separate prior to use. See **catalyst; epoxy plastic.**

adhesive, remoistening An adhesive system with dextrin, animal glue, gum Arabic, etc. that is reactivated by the deposit of water on the adhesive film.

adhesive, room-temperature cure An adhesive that sets to handling strength within at least an hour at temperatures from 20° to 30°C (68° to 86°F) and reaches full strength without heating. This room-temperature vulcanization is the vulcanization or curing at room temperature by chemical reaction, made up of two-part components of silicones and other elastomers/rubbers. RTV adhesives are used to withstand temperatures as high as 290°C (550°F) and as low as −160°C (−250°F) without losing their bond strength. A popular type uses silicone plastic. Their rapid curing makes them useful in applications such as adhesives, decorative potting, and flexible molds. See **zinc isopropyl xanthate adhesive, RTV;** See **adhesive, room-temperature cure.**

adhesive, scotch-tape test See **test, adhesive scotch-tape.**

adhesive, scrim cloth See **fabric scrim.**

adhesive set To convert an adhesive into a fixed or hardened state by chemical or physical action such as condensation, polymerization, oxidation, vulcanization, gelation, hydration, or evaporation of volatile constituents.

adhesive, silicone See **adhesive, room-temperature cure.**

adhesive slippage The movement of adherends with respect to each other during the bonding operation.

adhesive softener A material added to an adhesive to prevent its embrittlement. See **softener.**

adhesive, solvent A method of joining two thermoplastic types by applying a solvent to soften the part surfaces. Types have to be those that solvent will attack. Softening the plastic increases the movement of the plastic chains, allowing them to intermingle at the joint interface. Adhesion occurs after solvent evaporation. Solvent application must be carefully controlled to ensure optimal joint strength and to avoid damage to the part. With time the solvent can penetrate the plastic and cause damage either immediately or later when the plastic is in service. Solvent solutions that attack TPs are also used to determine the amount of undesirable "frozen stress" existing in parts. Also called *solvent fusion.* See **bonding; joining; orientation accidental; plasma arc treatment; satinizing; stress, frozen-in; solvent; test, residual stress; welding.**

adhesive solvent cement An adhesive made by dissolving a thermoplastic (usually compounded) in a suitable solvent or mixture of solvents.

adhesive spread The amount of adhesive (by weight) on the surface area of the bond lines, usually expressed in kg/100 cm^2 (lb/100 ft^2).

adhesive spreading See **doctor roll.**

adhesive starved joint An adhesive joint that has been deprived of the proper film thickness of adhesive due to insufficient adhesive spreading or to excessive application of pressure during processing.

adhesive strength A measure of the stress required to separate a layer of material from the base to which it is bonded. See **adhesive cohesive strength; adhesive peel strength; strength; stress.**

adhesive stress, internal Stress created within a material, such as an adhesive layer, by the movement of the adherends at differential rates or by the contraction or expansion of the adhesive layer. See **stress.**

adhesive stringing A condition occurring during an adhesive transfer process, characterized by webbing or incomplete breakoff when an adhesive film is split between rolls or between a stencil applicator when the uneven transfer of an adhesive occurs.

adhesive, structural See **structural bond.**

adhesive surface preparation See **surface treatment; transcrystalline growth.**

adhesive surface sodium treatment In adhesive bonding, a surface preparation technique in which the substrate is immersed in an aggressive etching solution containing either a sodium-naphthalene complex dissolved in tetrahydrofuran or a sodium-ammonia complex dissolved in ammonia. This process increases surface roughness and the potential for mechanical interlocking by dissolving the amorphous regions of the part surface and increases surface reactivity and wettability by introducing carbonyl and carboxyl functional groups and unsaturated bonds. Sodium treatment darkens the part surface to a depth of 1 mm and can substantially degrade the surface after extended exposure. Commonly used for fluorocarbons. See **amorphous plastic; crystalline plastic; surface treatment.**

adhesive tackifier A material added to the adhesive to improve the initial and extended tack range of the deposited adhesive film. See **tack.**

adhesive tack range The period of time in which an adhesive will remain in a tacky-dry condition after application to the adherend under specific conditions of temperature and humidity. Also called *adhesive tack stage.*

adhesive thickener See **polyvinyl pyrroldone plastic.**

adhesive throwing The undesirable splitting or transfer of adhesive globules onto machine components through the incomplete transfer of the adhesive during processing.

adhesive, transcrystalline growth See **transcrystalline growth.**

adhesive troweling To spread a high-viscosity adhesive by spatula, knife, spreader bar, etc. See **troweling.**

adhesive, two-part An adhesive in which the monomer and catalyst or hardener are separate from each other. The two reactive components separately have an indefinite storage life but must be mixed thoroughly before use. Room- and elevated-temperature cures are possible. Examples are two-part epoxy monomer and amine hardener, polyurethane, and peroxide-initiated adhesive systems, such as vulcanized silicone, unsaturated polyesters, and acrylics. See **adhesive, one-part.**

adhesive, warm-setting A term synonymous with the expression *intermediate-temperature-setting adhesive.*

adhesive, water soluble See **plastic, water soluble.**

adhesive, wood See **phenolic plastic; urea formaldehyde plastic; wood, laminated.**

adhesive wear In machinery components, the wear resulting from two metals rubbing against each other. An example is when the screw flight land comes in contact with the barrel liner during the operation of injection molding, extrusion, blow molding, etc. See **wear.**

adhesive webbing A condition of uneven transfer characterized by the stringing of the adhesive from the applicator mechanism and by the forming of a dried adhesive film that clings to the applicator.

adhesive welding See **welding, induction.**

adhesive wettability See **wettability; wetted; wetting agent.**

adhesive working time A measure of the interval of time during which an adhesive may be effectively applied to the adherend surface before adhesive setting retards the flow and alters the application properties of the adhesive. See **adhesive assembly time.**

adiabatic **1.** A change in pressure or volume without gain or loss in heat. See **heat, Gough-Joule effect; test, heat Wiegand pendulum.** **2.** A process or transformation in which no heat is added to or allowed to escape from the system. **3.** See **extruder, adiabatic.**

adiabatic calorimeter An instrument used to study chemical reactions that have a minimum loss of heat. See **calorimeter; chemical reaction.**

adiabatic flame temperature The highest possible temperature of combustion obtained when the burning occurs in an adiabatic vessel, the burning is complete, and dissociation does not occur. See **fire; flammability.**

Adiprene Uniroyal Chemical's trade name for its family of cast polyurethanes.

adjustable speed drive See **electric motor, adjustable speed drive; motion control system.**

adjusting volume See **blow molding, extruder bottle volume adjustment.**

administrative capability See **data management system.**

admixture An addition and homogeneous dispersion of discrete components before cure. See **mixture.**

adsorbate **1.** The material that is retained by the process of adsorption. **2.** Any substance that can be absorbed.

adsorption The adhesion of molecules of gases, dissolved substances, moisture, or liquids in more or less concentrated form to the surfaces of the solids (metal, etc.) or liquids with which they are in contact. Also called *physical* or *selective adsorption.* See **adsorption heat of; alumina, activated; carbon, activated; chemisorption; desorption; desiccant; moisture adsorption; persorption; sorbent; sorption; van der Waals adsorption; water adsorption; water pollution.**

adsorption, heat of Heat evolved during adsorption.

adsorption, hydrolytic The adsorption of a weak ionized acid or base formed by the hydrolysis of some type of salt in an aqueous solution.

adulterant A chemical impurity or substance that by law does not belong in food or any other regulated substance. See **packaging food.**

advanced composite See **reinforced plastic, advanced.**

advanced plastic See **plastic, advanced; commodity plastic; engineering plastic; reinforced plastic, advanced.**

advanced styrenic resin (ASR) A material produced either chemically in a reactor or by blending general-purpose polystyrene plastic and rubber in downstream operations. ASRs have good toughness, and processability. They may be used as an intermediate between high-impact polystyrene and acrylonitrile-butadiene-styrene plastic. See **polystyrene plastic; rubber.**

advancing reaction An in-progress chemical reaction that results in the curing of the plastic.

advantages and disadvantages of plastic See **plastic advantages and disadvantages; plastic myths and facts.**

aerated sand cleaning, hot Equipment used to clean plastic contaminated metal parts such as dies, molds, screen plates, screws, etc. A fluid bed of quartz crystals or aluminum oxide sand is set in motion by a raising stream of hot air or nitrogen at 410°C (800°F) that produces more even temperature than typical cleaning ovens. This hot aerated sand system can easily remove plastic from internal holes, assembled parts, etc. Parts to be cleaned are immersed in the fluid bed bath. See **cleaning.**

aeration **1.** A process of supplying air naturally or with equipment to solid waste, certain fabricating processes (such as blow molding and foaming), chemical reactions, etc. See **air; chemical reaction; pollution, water aerobic. 2.** A process of supplying air or oxygen to cure plastic, such as an aerobic adhesive. See **adhesive, aerobic; adhesive, anaerobic; curing agent.**

aerobic bacteria See **bacteria, aerobic; biodegradable; biodegradable waste; deodorant additive; environment; landfill and degradation.**

aerogel A porous solid form created from a gel by replacing liquid with gas with little change in volume so that the solid is highly porous. It is the reverse of an aerosol. Made of 99.9% air, aerogels appear more like solid smoke than gels but can support more than a thousand times their own weight. They are the lightest plastic solids. Aerogels are a hybrid between a gel and air and provide interesting characteristics, such as superinsulation and sound absorbtion, with very large surface areas.

Aerogel starts out as a delicate, three-dimensional framework of clusters of molecules linked together in a liquid medium. The linked clusters create a springy molecular mesh containing thousands of open pores filled with fluid, something like a wet sponge. To create the aerogel, the liquid must be removed carefully from the mesh. Under normal conditions, capillary pressures generated by evaporation of the liquid cause the framework to collapse on its self. As the gel's interior walls squeeze together, reactive molecules permanently bond, leaving a compressed semiporous gel that is a fraction of its original volume. This versatile material offers a wide range of uses from insulating windows and appliances to extracting salt from seawater. See **aerosol; gel; insulator; plastic, porous.**

aerosol A state of suspension or dispersion of extremely fine solid or liquid particles in a gaseous medium, usually air. Fog and smoke are common examples of natural aerosols. See **colloidal; suspension.**

aerosol fog A loose term applied to visible aerosols in which the dispersed phase is a condensation liquid.

aerospace market See **military market.**

aesthetic The external surface appearance of an object or product. Its elements may include color, shape, texture, feel, or other particular features of the product. The varieties of plastics available can provide virtually any desired aesthetic appearance. See **cosmetic market; design, innovative.**

affine deformation See **deformation, affine.**

affinity The attraction of one substance for another substance, such as the tendency of atoms or compounds to react or combine with atoms or compounds of different chemical constitution. There are attractions of polar similarity, such as between adhesives and adherend. See **adhesive.**

after-bake See **curing, post-.**

after-cure See **curing, after-.**

afterglow A glow in a material after the removal of an external source of fire exposure or after the cessation (natural or induced) of flaming material. See **phosphorescence.**

after mixer See **reaction injection molding.**

agent A substance, such as a catalyst, that produces an effect. See **catalyst.**

age resistance The ability of a material to resist aging.

agglomerate A cluster of particles of compounding materials contained in a continuous mass.

agglomerate, compounding material A cluster of particles of one or more compounding constituents held loosely together. See **compound.**

agglomeration, latex See **rubber latex, agglomerate.**

aggregate A hard, coarse fragmented filler material, usually of mineral origin. It can be used with an epoxy plastic binder as a flooring or surfacing medium, or in epoxy tools. See **filler, mineral.**

aging The change in properties of a material with time under stated conditions that could improve or deteriorate depending on the plastics used. See **accelerated aging.**

aging, air-bomb The process of exposing materials to the action of air at an elevated temperature and pressure.

aging, air-oven The process of exposing materials to the action of air at an elevated temperature at atmospheric pressure.

aging and molecular weight See **molecular weight and aging.**

aging annealing See **annealing.**

aging, anti- The process of hindering degradation by adding chemicals—for example, by oxidation.

aging, artificial The accelerated testing of material over a short period of time to indicate what may be expected of a material or product under service conditions over extended time periods. See **design and weathering weatherability, accelerated; weathering, artificial.**

aging inhibitor See **zinc.**

aging, life-cycle See **life-cycle analysis.**

aging, long life See **plastic long life.**
aging, machine See **machine aging.**
aging, over- The process of continuous aging of plastics until softening occurs.
aging, oxygen-bomb The process of exposing materials to the action of oxygen at an elevated temperature and pressure and then evaluating the effect of a concentration of oxygen on plastics.
aging, quench See **quench aging.**
aging retardant See **antioxidant agent.**
aging, shelf See **shelf life.**
aging, temperature-resistant See **antioxidant agent.**
aging, thermal See **thermal aging, relative thermal index.**
agitator A rotating or reciprocating device that induces motion in mixtures to uniformly disperse the components. See **mill; mixer.**
A-glass See **fiberglass type.**
agricultural biodegradable See **biodegradable.**
agriculture market An extensive market for plastic products. For example, film, which was introduced during the 1930s and 1940s, is desirable in all agricultural applications (mulching, fumigation, row covers, hot beds, controlled release of pesticides and nutrients, soil conditioning, seed planting, plant protection, farm equipment, greenhouses, animal shelters, water conservation, etc.). See **film; market.**
air A mixture or solution of gases. Its composition varies with altitude and other conditions at the collection point. The composition of dry air at sea level is in percent by weight 75.53 nitrogen (N_2) and 23.16 oxygen (O_2) or in percent by volume 78.0 N_2, 20.95 O_2, 0.93 argon, 0.033 carbon dioxide (CO_2), 0.0018 neon, 0.0005 helium (H_2), etc. See **aeration; atmosphere.**
air-assist forming See **thermoforming, air-assist.**
air atomization A process carried out by an air gun where a high-velocity air stream breaks up a liquid plastic or paint coating. Air atomization yields a smaller particle size than other spraying methods; the lower particle size limit is about 5 µm. Fine particle size allows good control of the coating thickness. The main disadvantage is considerable overspray (poor transfer efficiency) unless electrostatic spray coating assist is used. Pneumatic spraying is also inefficient from the point of view of energy utilization. Air guns not only atomize the paint but also shape the atomized stream. Usually a fan pattern is used because it allows better control of the coverage. See **coating, air-atomization; coating, electrostatic spray; foamed polyurethane; paint; spray, air atomization.**
airborne particle cleanliness See **cleanroom.**
air breathing Also called *mold bumping*. See **mold breathing.**
air-bubble defector void See **casting, vacuum; void content.**
air, clean See **automotive interior, low-emission plastic; incineration fume system; pollution, air.**
air conditioning The simultaneous control of at least the first three of the following factors affecting both the physical and chemical conditions of the atmosphere within any structure—temperature, humidity, motion, distribution, dust, bacteria, odor, and toxicity. See **antimicrobial agent.**
aircraft An extensive market for plastics. External and internal use of lightweight, durable, and high performance plastic in military and commercial aircraft includes reinforced plastics and specialty plastics such as antiicing coating. The successful 1944 U.S. Air Force all-plastic airplane (primary and secondary structures) used reinforced plastics (glass fiber with thermoset polyester hand layup that included the use of the lost-wax process) sandwich constructions for the monocoque fuselage, wings, and vertical stabilizer. Different RP parts (wing fairings, floor beams, rudder, elevators, engine cowl) are used on the Boeing 777. See **airship; energy and bottle; injection molding aircraft canopy; military market; polyphosphazene plastic; reinforced plastic soluble-core molding; soluble-core molding; Figure 5, Examples of Reinforced Plastics on the Boeing 777.**
aircraft, Gossamer Albatross A lightweight human-powered aircraft. On 12 June 1979, Californian Bryan Allen became the first person to fly 23 miles (38 km) across the English channel (2 h, 54 min) by using only his muscles to power a practically all-plastic aircraft weighing 70 lb (32 kg). He received a $200,000 prize from British industrialist Henry Kremer (to encourage human-power flight, a dream that goes back to Leonardo Da Vinci and even earlier). Extensive use was made of DuPont engineering plastics, such as Mylar (TP polyester film), Kevlar (aramid fiber), and Delrin (acetal).
aircraft radome See **radome; rain erosion.**
aircraft, Solar Challenger A lightweight solar-powered aircraft. On 7 July 1981, this sun-powered airplane made aviation history by flying 230 miles (370 km) from France to England in 5 h and 23 min. Its 16,128 wing-mounted solar cells powered an all-plastic lightweight plane of 217 lb (98 kg). It used DuPont's Kevlar aramid fiber reinforced plastic structures, Mylar shrunk polyester film outboard skins, Delrin acetal control pulleys, and Zytel ST supertough nylon landing gear wheel.
aircraft arrester See **foamed ground aircraft arrester.**
air density, standard The atmospheric air density, is 0.0750 lb/ft^3 (1.201 kg/m^3) at a temperature of 68°F (20°C), 14.696 psi (101.32 kPa), and approximately 30 percent relative humidity.
air, dry Air containing no water.
air entrapment A phenomenon wherein air is occulated in a plastic or composite system giving rise to blister bubbles or voids that are usually not desired. It can occur during fabrication. The bubbles may be caused by air or moisture due to improper plastic material drying, by compounding agent volatiles, by plastic degradation, or by the use of contaminated regrind. The first step to resolving this problem is to determine what is causing it. A logical

troubleshooting approach can be used. See **bubble; casting; deaerate; defoamer additive; drying; material inclusion; recycling plastic; troubleshooting; void content.**

air floatation or felting process See **fabric, nonwoven.**

air flow See **conservation of matter, law of.**

air flow value See **foamed-air flow level.**

air gap See **extruder coating and lamination air gap.**

air-inhibited plastic See **plastic, air-inhibited.**

air knife See **coating, air-knife; extruder sheet air knife.**

air lock See **molded air lock.**

air noninhibited plastic See **plastic, air noninhibited.**

airplane See **aircraft.**

air pocket, trapped An internal pocket of air or other gas; not a general condition as with porosity. See **porosity.**

air pressure See **blow-molding air pressure.**

air-pressure differential See **thermoforming, pneumatic-control.**

air quality See **vinyl composition tile.**

air removal See **deaerate.**

air ring See **extruder-blown film air entrapment.**

air, saturated A mixture of dry air and water vapor in which the latter is at its maximum concentration for the prevailing temperature and pressure. See **saturation.**

airship An aircraft. Inflatable airships use different plastics to provide strength, durability, and light weight in the environment, such as polyester fabric coated with neoprene, reinforced plastic gondolas, etc. See **aircraft.**

air shot See **injection-molding air shot.**

air-slip forming See **thermoforming, air-slip.**

air vent A small outlet that prevents the entrapment of air and other gases. See **autoclave venting; mold-cavity venting; mold venting, water transfer; reinforced-plastic processing vent cloth; screw venting; venting.**

air-void curve, zero A saturation curve that shows the zero air voids as a function of water content. Unit weight is in weight per unit volume.

Alathon A trade name for DuPont's family of polyethylene plastics.

albumin See **fixing agent.**

alchemy See **chemical science alchemy.**

alcohol A carbon-containing compound with a hydroxyl group (-OH). See **ester.**

alcohol, absolute Ethyl alcohol that contains no more than 1% water. Also called *anhydrous alcohol.*

Alcryn A trade name for DuPont's family of melt-processable elastomers and rubbers.

aldehyde A volatile liquid with a sharp, penetrating odor that is slightly less soluble in water than alcohol and can also be used with different plastics for cleaning, etc. See **chemical reaction, Gatterman; cleaning, solvent.**

aldehyde polymerization See **polymerization, aldehyde.**

algebra A generalization of arithmetic in which letters representing numbers are combined according to the rules of arithmetic. See **arithmetic; computer science and algebra; mathematics; mean, arithmetic; range.**

algebra, transfinite A branch of higher mathematics dealing with the algebra of infinity.

algorithm 1. An abstract description of a procedure or a program. **2.** A specified, step-by-step procedure for performing a task that will lead to a correct answer or solving a problem. Also known as a *flow chart.* See **computerized knowledge-based engineering; computer procedure-oriented language; flow chart; temperature proportional-integral-derivative.**

algorithm, recognition A computer program or instruction set used to recognize specific phenomena from a processing of data acquired for the system from some external source. See **computer.**

algorithms and artificial intelligence See **intelligence, artificial.**

algorithms, generic (GA) A class of machine-learning techniques that are similar to processes that occur in the interactions of natural, biological genes. Thus, GA is a method of finding a good answer to a problem, based on feedback received from repeated attempts to obtain a solution. Each attempt is called a *gene.* See **problem and solution.**

alignment, barrel See **barrel borescoping.**

alignment, equipment See **machine alignment.**

aligomer See **molecule, telomer.**

aliphatic hydrocarbon A saturated hydrocarbon that has an open-chain structure, such as propane and gasoline. See **molecule, aliphatic.**

alkali A substance that is soluble in water, can form a solution, and can neutralize an acid. More technically, the term applies to the hydroxides and carbonates of the alkali metals.

alkali metals and derivatives The alkali metals, which include lithium, sodium, potassium, cesium, and francium. They make up the Group 1A elements of the periodic table system. Because of their high reactivity, all except francium are used in virtually every area of organic polymer synthesis, including many aspects of polymerization chemistry. See **chemical reaction; periodic table; polymerization.**

alkyd molding compound A thermoset plastic that is compounded with low amounts of cross-linking monomer and fillers, lubricants, pigments, and catalysts. Their principal use is in the matrix of reinforced plastics. See **alkyd plastic; reinforced-plastic bulk-molding compound.**

alkyd plastic A thermoset polyester plastic that is made with a fatty acid as a modifier. The term *alkyd* should be used with care. It originally designated resinous-reaction products of di- and polyhydric alcohols and acids, which when modified with reactive monomers are called *thermoset polyester plastics.* When modified with nonvolatile monomers such as diallyl phthalate to form dry or relatively dry molding compounds, they are called *alkyd plastics.* When curing, alkyd plastics do not yield (condense) water as much as some of the other thermoset plastics, and therefore curing can be accomplished from zero to any amount of pressure. They provide dimensional stability and are widely used in surface-coating formulations and in molding compounds. Also known as *glyptal plastics* and *thermoset polyester plastics.* See **catalyst, benzoyl peroxide; coating, air-drying alkyd-plastic; diallyl phthalate plastic; maleic anhydride; phthalic anhydride; polyester plastic, thermoset.**

alkylate sulfonate, linear (LAS) The world's largest-volume synthetic surfactant. Household detergents, principally laundry powders and liquids, and dishwashing liquids, consume about 85 to 90 percent of the total. Other use includes plastics. See **detergent; surfactant.**

allergen See **medical antibody and antigen plastic-encapsulated.**

alligator-grained surface A plastic surface that is embossed to resemble the grain of an alligator hide.

alligatoring **1.** A reinforced plastic or laminate surface flaw that resembles the texture of an alligator's skin. **2.** See **melt fracture.**

allophanate See **isocyanate allophanate.**

alloprene plastic A chlorinated elastomer.

allotropy The existence of a substance, especially an element, in two or more physical states, such as crystal and graphite. See **graphitization.**

allowable property See **A-basis; B-basis; S-basis; typical basis.**

allowance See **tolerance allowance.**

alloy/blend A composite material that is blended from many different basic materials. Alloys or blends include plastics, chemicals, paints, metals, and nonmetals. A plastic alloy or blend is a composite that is constructed by blending polymers/plastics or copolymers with other polymers or elastomers under selected conditions to retain the best characteristics of each constituent. They are mechanically blended; they do not depend on chemical bonds but often require special compatibilizers. Alloys and blends are continuously being developed to meet industry new performance requirements. The terms *alloy* and *blend* are often used interchangeably, but generally an alloy is a subclass of plastic blends. Examples include ABS/nylon, which is made compatible with additives and offers improved chemical resistance, surface lubricity, etc.; ABS/PC, which offers good processability, etc.; and ABS/TPU offers improved flex fatigue, vibration clamping, and cold temperature toughness. See **blending; chemical composition and plastic property; composite; compound; die-casting alloy; elastomeric alloy; interpenetrating network; material-blending letdown ratio; material, microphase structure; miscibility; plastic-glass alloy; polymer, reactive; polypropylene multiple monomer; synergism.**

alloy constitutional diagram A graphical representation of the compositions, temperatures, and pressures at which heterogeneous equilibrium of an alloy system occurs. Also called *phase diagram* or *equilibrium diagram.*

alloy, metal molding See **injection molding nonplastic.**

alloy, steel See **iron; metal.**

alloy, super- A plastic, alloy that combines high temperature-mechanical properties, oxidation resistance, and creep resistance to an unusual high degree. Examples include iron-base, cobalt-base or nickel-base plastic alloys.

allyl ester plastic A family of transparent thermoset plastics. Their properties are generally better than those of other organic transparent materials.

allyl diglycol carbonate plastic A branch of the thermoset polyester plastic family that is formed by the addition polymerization of chemical compounds containing allyl groups. An example of a true allylic homopolymer cast from the monomer is diethylene glycol bis (allyl carbonate), which has been sold by PPG since at least the 1940s under the trade name CR-39. It has exceptionally good optical transparency, with excellent hardness and scratch resistance, and is used in all types of sunglasses and eyeglasses, heat protection face shields, etc. The most widely used in this family of plastics is diallyl phthalate plastic. See **diallyl phthalate plastic; polyester plastic, thermoset.**

allyl plastic A branch of the thermoset polyester family of plastics that is among the most versatile of the thermoset plastics. Allyl plastics can be homopolymerized or copolymerized with alkyds, etc. See **alkyd plastic; polymerization; polyester plastic, thermoset.**

alpha See **atom, alpha.**

alpha cellulose See **cellulose, alpha.**

alpha loss peak See **dynamic mechanical analysis, alpha loss peak.**

alphanumeric A character set that contains both letters and digits.

alternating copolymer See **copolymer, alternating.**

alternating current See **electrical alternating current.**

alternating-amplitude stress See **stress, alternating-amplitude.**

alumina, activated A highly porous granular form of aluminum oxide that has preferential adsorptive capacity for the moisture and odor that are contained in gases and some liquids. It is an effective desiccant and also is used as a catalyst or catalyst carrier in chromatography. See **adsorption; catalyst; chromatography; desiccant; odor.**

alumina-silica fiber See **fiber, alumina-silica.**

alumina trihydrate An inert, white, crystalline mineral powder filler that provides flame retardance and electrical arc and track resistance to plastics. It also is used as a reinforcing agent in elastomers, paper coating, cosmetics, etc. See **flame retardant; insulation resistance; pigment, extended.**

alumina white-ware A ceramic white-ware in which alumina (Al_2O_3) is the essential crystalline phase.

aluminized film See **metallizing plastic.**

aluminosilicate glass See **glass composition.**

aluminum (Al) The third most abundant metal in the earth's crust. It does not occur free in nature but is derived from mined bauxite, which is processed through various techniques, is processed subsequently via electrolytic reduction, and produces hundreds of alloys. See **mold material; machining safety; metal, light; waste; zinc.**

aluminum alkyl See **catalyst, aluminum alkyl.**

aluminum alloy See **kirksite.**

aluminum foil A solid sheet of an appropriate aluminum alloy, cold-rolled very thin from a minimum thickness of about 0.0017 in. (0.00432 mm) to a maximum of about 0.0059 in. (0.1499 mm). In the aluminum industry, a thickness of at least 0.006 in. (0.1524 mm) is sheet material (sheet). After (oil) cold-rolling, the foil is annealed to restore its workability. From the standpoint of packaging as well as other applications, one of its most important characteristics is its impermeability to water vapor or gases. Bare foil 1.5 mil (0.0015 in. or 0.0038 mm) and thicker is completely impermeable and used in plastic coating and packaging process systems. See **barrier, plastic; foil decorating; laminate, decorative.**

aluminum, injection-molding See **injection-molding, nonplastic.**

aluminum modulus versus specific gravity See **modulus versus specific gravity.**

aluminum mold See **mold material.**

aluminum molding See **injection molding, nonplastic.**

aluminum permeability See **aluminum foil.**

aluminum stearate An aluminum soap in the form of a white powder that is insoluble in water and soluble in oils. It is used as a dryer in creating paints and varnishes, waterproofing fabrics and concrete, etc. See **paint; varnish; waterproofing.**

aluminum wettability test See **test, aluminum wettability.**

amber plastic A natural fossil plastic formed principally on the shores of the Baltic Sea. Although largely replaced for most applications by phenolformaldehyde, the material is still used as the basis of certain varnishes and dyes. See **plastic, natural.**

American Plastics Council (APC) An organization that (1) educates students in grade schools through colleges and engineers, designers, and company executives about the benefits and advantages of plastics and (2) enhances the skills of those people who already work in plastics. The council's membership is comprised of plastic manufacturers.

American Standards for Testing Materials (ASTM) A world authority on standards for testing all types of materials that include plastics. Founded in the nineteenth century, its headquarters now are in West Conshohocken, Pennsylvania. It publishes thousands of standards every year that are updated when required. See **ISO; ISO-10993 standard; sterilization radiation, certification worldwide.**

amide-imide plastic See **polyimide plastic.**

amine adduct A product of the reaction of an amine with a deficiency of a substance containing epoxy groups.

amine plastic A material that is derived from the reaction of urea, thiourea, melamine, or allied compounds with aldehydes, particularly formaldehyde.

aminolysis See **recycling, chemical.**

amino plastic A family of thermoset plastics that is the reaction product of amino compounds with aldehydes. The amino monomer is characteristically present as amide—for example, in urea formaldehyde plastic and melamine formaldehyde plastic. The results are hard, colorless, transparent plastics generally referred to as *amino plastics*. See **urea formaldehyde plastic.**

ammonia (NH_3) The basic building block of the world nitrogen industry and the intermediate product from which a wide variety of nitrogen fertilizer materials and industrial products (plastics, explosives, etc.) are produced.

ammonia anhydrous A colorless gas or liquid that has sharp and intensely irritant odor, is lighter than air, and is very soluble in water, alcohol, etc. It is the third-highest volume chemical produced in the United States. It is used in plastic formulations (PUR, AN, etc.), fibers, latex preservatives, etc.

amorphous domain A phase of plastic material that is without a regular form, not crystalline, and in a highly disordered state. This morphological term is used to refer to noncrystalline systems, such as block copolymers, in which the chemically different sections of the chain separate generating two or more amorphous phases.

amorphous plastic A thermoplastic that has no crystalline plastic structure. These TPs have no sharp melting point and are usually glassy and transparent, such as polystyrene and acrylic (PMMA). If they are rigid, they may be brittle. Plastics during processing are normally in the amorphous state with no definite order of molecule chains. TPs that normally crystallize (crystalline plastics) may not be properly quenched when hot melt is cooled to solidify the plastic and may result in an amorphous or partially amorphous solid state that usually has inferior properties. See **annealing; commodity plastic; cooling, super-; crystalline plastic; engineering plastic; glass transition temperature; heat capacity; heat profile; melt flow; melting temperature; mold cooling rate; molecular arrangement structure; morphology; nylon plastic, amorphous; plastic solidification; semicrystalline plastic; Staudinger, Hermann; temperature and molecular bonding force.**

amorphous plastic and polarized light See **polarized light.**

amorphous plastic nylon See **nylon plastic, amorphous; nylon plastic type; transparent plastic.**
amorphous plastic orientation A component of the overall orientation that is due to the amorphous regions in a plastic. Each anisotropic property will have an amorphous component, such as birefringence. See **birefringence; directional property, anisotropic; orientation.**
amorphous plastic region A region in a crystalline plastic that has not crystallized and therefore has polymer chains that exist in the random configuration where the polymer is amorphous. Since crystallization is limited in a crystalline plastic, amorphous regions are always present, typically accounting for up to about 20 percent of the plastic. Thus, the plastic acts as a composite of amorphous and crystalline polymers. Both regions contribute their characteristic properties to the overall behavior, with amorphous regions exhibiting a glass transition temperature. See **crystalline plastic; glass transition temperature.**
amorphous plastic scatter The x-ray scattering produced by an amorphous plastic. Although no short- or long-range order of a crystalline kind exists, a short-range order of the most probable distance between neighboring atoms does exist. This is often expressed in terms of the atomic radial distribution function, obtained from a scatter curve. See **x-ray scattering, long period.**
amorphous second-order transition The change from an amorphous state to a plastic state.
amortized See **business amortization.**
amosite A fibrous amphibole asbestos similar to crocidolite, containing a higher portion of iron than anthophyllite asbestos fibers. See **asbestos.**
ampere See **electrical ampere.**
amphoteric See **chemical, amphoteric.**
amplitude The vertical distance from midline of the peak or the trough of a wave; the difference between the average value of a sinusoidal variation and the maximum (or minimum) value.
anaerobic See **adhesive, anaerobic.**
analog Information that is continuously variable and thus has infinite possible values. It is unlike digital information, which is discrete and binary and has only two possible values (on/off, high/low). See **computer analog-to-digital converter; digital; motion control system.**
analysis failure See **DART software; problem and solution.**
analytical instrument An instrument that determines such material characteristics as composition, molecular weight, and degree of crystallinity. Examples include the infrared spectrophotometer, gel permeation chromatography, and different scanning calorimeter. See **chromatography, gel-permeation; differential-scanning calorimetry; spectrophotometer.**
analytical tool See **Deere JD/GTS software.**
anelasticity deformation See **deformation, viscous.**
angel hair See **material, cutting burr-free.**
angstrom A unit of length that is the wavelength of the red line of cadmium (6438,4696 A). For practical purposes it is one hundred millionth (10^{-8}) of a centimeter—ten thousand times smaller than a micron-size particle. See **micron; nanotechnology.**
anhydrous A compound that does not contain water or that has had water extracted from it.
anilene An organic base made by reacting chlorobenzene with aqueous ammonia in the presence of a catalyst. It is used in the production of aniline formaldehyde plastics and in the manufacture of certain rubbers, dyes, and drugs. See **accelerator; antioxidant agent.**
anilene-formaldehyde plastic An amino plastic that is made by the condensation of formaldehyde and anilene in an acid solution. These thermoplastics have high dielectric strength and good chemical resistance.
anion See **ion.**
anisotropic See **directional property, anisotropic.**
annealing A heat-treatment process that is intended to improve performance by removing stresses or strains set up in the material during its fabrication. The plastic is brought up to a required temperature for a definite time period (depending on the type of plastic), and then cooled by liquid (usually water but sometimes oils and waxes) or air (quenched) to room temperature at a controlled rate. The temperature is near, but below, the melting point. At the specified temperature the molecules have enough mobility to allow them to orient to a configuration and thereby to remove or reduce residual stress. The objective is to permit stress relaxation without distortion of shape and to obtain maximum performances or dimensional control.

Annealing is generally restricted to thermoplastics, either amorphous or crystalline. Because it increases density, it thereby improves the plastics' heat resistance and dimensional stability when exposed to elevated temperatures. It frequently improves impact strength and prevents crazing and cracking of excessively stressed products. The magnitude of these changes depends on the nature of the plastic, the annealing conditions, and the parts geometry.

The most desirable annealing temperatures for amorphous plastics, certain blends, and block copolymers is above their glass transition temperature (T_g), where the relaxation of stress and orientation is the most rapid. However, the required temperatures may cause excessive distortion and warping. The plastic is heated to the highest temperature at which dimensional changes owing to strain are released. This temperature can be determined by placing the plastic part in an air oven or water liquid bath and gradually raising the temperature by intervals of 3° to 5°C until the maximum allowable change in shape or dimension occurs. This distortion temperature is dictated by the thermomechanical processing history, geometry, thickness, and size. Usually the annealing temperature is set about 5°C lower using careful quality-control procedures.

Rigid, amorphous plastics such as polystyrene and acrylic are frequently annealed for stress relief. Annealing crystalline plastics, in addition to the usual stress relief, may also bring about significant changes in the nature of their crystalline state, depending on the nature of the crystal structure, degree of crystallinity, size and number of spherulites, and orientation. In cases when proper temperature and pressure are maintained during processing, the induced internal stresses may be insignificant, and annealing is not required.

Plastic blends and block copolymers typically contain other low and intermediate molecular weight additives such as plasticizers, flame retardants, and ultraviolet or thermal stabilizers. During annealing, phase and microphase separation may be enhanced, and bleeding of the additives may be observed. The morphologies of blends and block copolymers can be affected by processing and quenching conditions. If their melt viscosities are not matched, compositional layering perpendicular to the direction of flow may occur. As in the case of crystalline plastics, the skin may be different both in morphology and composition. Annealing may cause more significant changes in the skin than in the interior. Also called, *hardening, tempering, physical aging*, and *heat treatment*. See **amorphous plastic; crystalline plastic; flame annealing; glass transition temperature; hardening, case; infrared annealing; insert molding; quench; screw heat treatment; stress, frozen-in; stress, residual; temper; temperature sensitivity; test, deflection temperature under load; tolerance and shrinkage.**

annihilation See **antiparticle.**

antiaging See **aging, anti-.**

antiblocking agent An additive that stops blocking or sticking of two surfaces and that usually is associated with films. Antiblocking agents are used extensively in the production of polyethylene packaging film, where they ensure that bags made from the film will open easily when used during packaging operations. The agent can be mixed into the plastics or applied on the surface after manufacture. The concentration of agents in the material varies from 0.1% to 1%, based on the weight of the plastic. Chemicals that are used in the blends include stearamide, stearoguanamine, metal salts of fatty acids (calcium stearate), polyethylene, copolymers of vinyl acetate with either maleic anhydride, or ethyl acrylate. Chemicals that may be applied to the surface either during or after extrusion include colloidal silica, clays, starches, silicones, etc. See **abherent; additive, slip; blockage; dusting agent; film blocking; sheet blocking; sweating.**

anticaking agent An additive used primarily in certain finely divided compounds that tend to be hygroscopic to prevent or inhibit agglomeration and thus maintain a free-flowing condition of the material. See **material handling.**

anticoagulant agent A substance that retards or prevents the coalescence of colloidal particles. Also law called *stabilizer agent* in latex terminology. See **coagulation.**

antidust agent See **calcium chloride; dust.**

antifoaming agent A material that is used in the prevention and control of unwanted foam. Although antifoaming agents are foam-preventative materials and defoaming agents or defoamers are foam reducers, these terms are used interchangeably. Foamed substances are dispersions of air or other gas as the discontinuous phase in an otherwise continuous liquid phase. Usually, since air or gas makes up the larger volume portion of such foam, only a thin liquid film (lamella) separates the bubbles. Unwanted fluid foams are comprised of thousands of tiny uniform bubbles of mechanical or chemical origin that are generated within a liquid and that rise and accumulate at the liquid surface faster than they decay. Problems are diverse, ranging from unaesthetic foams to foams hazardous to life, and include polymerization reactions, coatings, adhesives, etc. Solutions to the problems are by means mechanical or a chemical antifoaming agent. Also called *foam inhibitor*. See **defoamer additive; foam; lamella.**

antifogging agent A material that prevents fogging of clear products such as packaging films. Fogging can occur when water condenses on the inside of packaged food, etc. The agent, typically a fatty acid ester, either causes the water droplets to form a continuous film or imparts a hydrophobic characteristic to the film surface to prevent water droplets from forming. See **emulsifying agent; hydrophobic.**

antifouling coating See **coating, antifouling; pigment.**

antifreeze See **calcium chloride; ethylene glycol.**

antifriction compound A plastic that is specifically formulated to reduce or eliminate friction. See **friction; silicone plastic.**

antigelling agent An additive that prevents a solution from forming a gel. See **gel.**

antiicing coating See **polyphosphazene plastic.**

aniline See **ink, aniline.**

antimicrobial agent A material added to plastic products such as those used in building and construction to ward off what the medical industry has referred to as *sick-building syndrome* and *building-related illness*. These side effects of indoors microbial growth have become more noticeable with the construction of better-insulated, more energy-efficient homes, offices, hotels, and automobiles. Typical of such maladies is legionnaire's disease, which was first brought to public awareness during an outbreak of pneumonialike sickness among attendees of a 1976 American Legion Convention at the original Bellevue-Stratford Hotel (completely destroyed during the 1980s and replaced by a new Bellevue) in Philadelphia.

The cause was a bacterium isolated in the hotel's air conditioning system. In many buildings, high densities of fungi and bacteria have been found in carpets, wall coverings, hot tubs, shower heads, drains, shower curtains, refrigerator doors, etc. and in different products such as those used for healthcare and cosmetics. See **air conditioning; bacteria; biodegradable; biodegradable and waste; deodorant additive; environment; landfill and degradation.**

antimony oxide (Sb_2O_3) A white, colorless, fine powder chemical that is used as a flame retardant, pigment, catalyst, chemical intermediate, and lubricant. See **catalyst; flame retardant; lubricant.**

antimony pentoxide A material that is used as a flame retardant. Also called *antimonic anhydride, antimonic acid*, or *stibic anhydride*. See **flame retardant.**

antimony trioxide A material that is used in flameproofing plastics, textiles, and papers; in creating paint pigments, especially PVC; and as a catalyst or intermediate in organic reactions. Also called *antimony white* or *antimony oxide*. See **catalyst; flammability; pigment.**

antionic See **emulsifying agent.**

antioxidant agent (AOA) A substance that opposes oxidation or inhibits reactions promoted by oxygen or peroxides. In plastics, antioxidant agents retard oxidation during processing heat, atmospheric oxidation, or the degrading effects of oxidation. Certain plastics, such as polyethylene, are susceptible to degradation that starts when free radicals are released after exposure to heat, ultraviolet radiation, and mechanical shear or in the presence of reactive impurities such as catalyst residues. There are also nonstaining antioxidants. Antiozonant agents control oxidative degradation by ozone. AOAs are of major importance to the plastic industry because they extend the useful temperature range and service life of plastics that are effected by oxygen during processing or product use. The variety of AOAs available and their specific uses are extensive. Also called *aging retardants*. See **aging; electrical corona; oxidation degradation, thermal; photochemistry; stabilizer; stain, antioxidant non-; stain-resistant agent.**

antiozonant agent A substance that prevents or slows down oxidation of plastics effected by ozone. Frequently, the protective effect results from a reaction with ozone, in which case the term used is *chemical antiozonant*. Protection against ozone includes the addition to plastics of wax additives (paraffin or microcrystalline type) or inert plastics. See **oxidation; ozone.**

antiparticle A subatomic particle that has the same mass and spin as one of the particles of ordinary matter but has the opposite value of electric charge and magnetic moment. When the particle meets its corresponding antiparticle, they both disappear in a scientific process called *annihilation* that results in the total mass of the pair being converted into energy. This discovery was first made during 1932. See **particle.**

antirad See **radiation induced reaction.**

antisag agent See **sag; thickening agent.**

antislip agent A material that creates a certain degree of blocking between surfaces, such as where filled plastic bags cannot be stacked because they tend to slide or where plastic fibers made into fabrics give excess slip. Both internal and external agents are used. Copolymers of ethylene and maleic anhydride, colloidal silica, finely powdered sand, mica, and other minerals effectively reduce slippage when compounded or sprayed. Colloidal silica solutions, diluted with water, are primarily used for spraying surfaces. When compounded into the plastics, they are of small particle size, less than 1μ, and the amount used is less than 1wt%. Also called *slip depressants*. See **additive, slip; antiblocking agent; lubricant; packaging, grocery bag; sweating.**

antistatic agent A material that minimizes static electricity in plastics. Metallic antistatic devices come in contact with the plastics and conduct the static charge to earth, and chemical antistatic agents are mixed with the compound prior or during processing and give a reasonable degree of protection to the finished product by being inherently conductive or by absorbing moisture from the air to release the static charge. Also called *antistat*. See **electromagnetic interference; extruder sheet antistatic bath; moisture, humectant agent; packaging, electronic; static charge; thickening agent.**

antistatic plastic and electronic packaging See **design, biomedical product; packaging, electronic.**

antitrust law See **legal matter: patent pooling with competitors.**

antiwear additive An additive that is used to reduce surface wear. See **wear.**

apochromatic See **lens, apochromatic.**

apparel Clothes use plastics in fiber constructions, insulation, form fittings, etc. to meet different performance requirements. See **fabric; zipper.**

apparent density See **density, apparent.**

apparent specific gravity See **specific gravity, apparent.**

apparent viscosity See **viscosity, apparent.**

applesauce surface A rough, wavy appearance on a part. See **defect; orange peel.**

appliance market A market where most appliances incorporate plastics of many types that contribute to their beauty and performance.

application for plastic See **market.**

aqua Latin for *water*. See **water.**

aqueous See **coating, waterborne system; water-aqueous.**

aqueous polymerization See **polymerization, aqueous.**

aqueous system See **coating, waterborne system.**

Araldite A trade name for Ciba-Geigy's family of epoxy plastic accelerators.

aramid fiber See **fiber, nylon; Kevlar.**

arbor See **roll arbor.**

architectural market See **building and construction market; vinyl composition tile.**

architecture, computer See **computer architecture.**

arc resistance See **electrical are resistance.**

area, circular-mil A unit of area equal to $\pi/4$ (0.7854) of a square mil. The cross-sectional area of a circle in circular mils is therefore equal to the square of its diameter in mils. A circular inch is equal to one million circular mils. See **mil.**

area, circle The area of a circle equals its radius squared: $A = r^2$

area under the stress-strain curve See **tensile stress-strain curve.**

area, world See **world area.**

areal weight See **reinforced plastic weight, areal.**

Ardel A trade name for Amoco's family of polyarylate plastics.

arithmetic A branch of mathematics that deals with real numbers and computations with these numbers. See **algebra; mean, arithmetic.**

arithmetic logic unit See **computer arithmetic logic unit; mean, arithmetic.**

Arnite A trade name for Akzo Chemical's high intrinsic viscosity PET that can be extrusion blow molded.

aromatic An unsaturated hydrocarbon with one or more benzene ring structures in the molecule. The name refers to the strong and unpleasant odor of most substances of this nature. See **chemical benzene ring; radiation-induced reaction.**

aromatic hydrocarbon A hydrocarbon, such as benzene or toluene, that is derived from or characterized by the presence of unsaturated resonant ring structures. Aromatic hydrocarbons are largely obtained from crude oil by refinery process.

aromatic polyamide fiber See **fiber, nylon.**

aromatic polyester ester carbonate plastic A plastic that has increased heat distortion temperature when compared to general-purpose polycarbonate plastic. Also called *polyester carbonate, aromatic polyester carbonate,* or *aromatic ester carbonate.* See **polycarbonate plastic.**

aromatic polyester plastic See **polyester plastic, aromatic.**

aromatic substance A benzene ring that possesses a six-number unsaturated carbon ring as part of its constituent structure. See **chemical benzene ring.**

Arrhenius equation An equation that refers to the rates of reaction versus temperature. See **chemical reaction versus temperature rate.**

arrowhead See **extruder film arrowhead.**

art and weatherability See **weatherability, accelerated.**

art and science Product design is as much an art as a science. Guidelines exist regarding meeting and complying with art and science. See **automation; computer-aided; design, innovative; experience and science; graphic art; plastic material selection; productivity; scientific method.**

artificial intelligence See **intelligence, artificial.**

artificial weathering See **weathering, artificial.**

artwork Original design including drawings and text. See **black and white; computer-aided design; computer drawing; computer picture-level benchmark; design, engineering; design graphic; graphic art; photography, camera-ready.**

artwork, photoplotter A device used to generate artwork photographically for printed circuit boards. See **printed circuit board; printing, screen-photoimage.**

aryl group See **chemical benzene ring aryl group.**

asbestic A short type of asbestos.

asbestine A soft fibrous magnesium silicate. It is used as a filler in plastics, elastomers, and papers.

asbestos A commercial term, not the name of a distinct mineral species, applied to fibrous varieties of several silicate minerals such as amosite and crocidolite. These extremely fine fibers are useful as fillers and reinforcements in plastics. Property performances include withstanding wear and high temperatures, chemical resistance, and strengths with high modulus of elasticity. Like other fibrous materials, when they are not properly handled or used, they can be hazardous. See **amosite; crocidolite; fiber carding; machining safety; phenolic plastic; test, tunnel fire.**

asbestos roving An assemblage of carded asbestos, with or without other fibers, that is formed into a single strand without twist. See **cordage; roving.**

A-scan See **computer A-scan.**

aseptic packaging See **packaging, aseptic.**

ash **1.** An inert residue that remains after the complete combustion of plastic, paper, coal, etc. It is used as a filler in plastics, paints, etc. See **filler. 2.** The end product of large-scale coal combustion, as in power plants, that consists principally of fly ash. **3.** In regard to environmental waste, the inert residue that remains after solid waste is incinerated. Ash or ash residue can include minerals, ceramics, metal, etc. See **incineration.**

ash, bone A noncombustible ash that is composed principally of tribasic phosphate but contains minor amounts of magnesium phosphate, calcium carbonate, and calcium fluoride. It is obtained from calcimining bones, or from synthetic products. It is used in cleaning and polishing, coating molds, etc. See **polish.**

ash content The percentage of inorganic content in a plastic. It is the elimination or reduction of plastic by high heat (muffle furnace, etc.) to yield any inorganic fillers or reinforcements; it is also the solid residue remaining after a plastic substance, such as glass-fiber-reinforced plastic, has been incinerated. See **fiberglass binder/sizing coupling agent; incineration; reinforced plastic ignition loss.**

ashing A finishing process used to produce a satinlike finish on plastic products, to remove cold spots or teardrops from irregular surfaces, etc. For example, a part is applied to a loose muslin disk loaded with wet ground pumice in a rotating drum traveling at speeds of 4,000 linear ft/m. See **buffing; finishing, ashing and lapping; plating; polish; pumice; sanding; surface finish.**

askarel See **electrical insulation, askarel.**

aspect ratio **1.** The ratio of length to diameter of a material such as a fiber or rod; the ratio of the major to minor axis lengths of a material such as a particle. Both ratios can be used in determining the effect of dispersed additive fibers or particles on the viscosity of a fluid/melt and in turn on the performance of the compound based on L/D ratios. In reinforced plastics, fiber L/D will have a direct influence on the reinforced plastic performance. See **reinforced plastic; reinforcement, disk; reinforcement, whisker; slenderness ratio. 2.** The ratio of length to diameter (L/D) for a plasticator screw or the barrel hole. See **screw length-to-diameter ratio.**

asperity See **surface, asperity.**

asphalt A dark-colored solid or semisolid material that liquefies on heating. It is often found in nature or may be obtained from the distillation of crude oil. See **coumarone-indene plastic.**

assay See **chemical assay.**

assembly The unification of components or products into a finished operation or product. See **auxiliary equipment; design; design consolidation and minimize material; design, disassembly.**

assembly and disassembly See **design, snap-fit.**

assembler 1. A program that translates assembly language instructions into machine language. **2.** A person or device that assembles parts.

assembly drawing A drawing representing a group of parts constituting major subdivisions of the final product. See **artwork.**

assembly/joining Methods that are used for joining or fastening and assembling plastic products and plastic to other materials. Both designer and end-user need to understand the techniques, advantages, and limitations of these methods so that intelligent choices can be made. For example, a product that includes plastic to plastic and plastic to metal assemblings that have different thermal expansions could fail. Methods of thermoplastics parts assembly for high-volume production include solvent bonding, adhesive bonding, ultrasonic welding, hot tool welding, electromagnetic and induction bonding, and dielectric heat welding. Thermoplastics assembly methods for low-volume production include gas welding, adhesive bonding, ultrasonic tool welding, hot tool welding, and spin welding. Thermoset plastics for high-volume production include molded-in inserts, mechanical fasteners, adhesive bonds, and electromagnetic and induction heating of adhesives; thermoset plastics assembly methods for low-volume production include adhesive bonding and mechanical fastening. See **adhesive; auxiliary equipment; bonding; coefficient of linear thermal expansion; joining; nail; nominal value; orientation and heat-shrinkability; subassembly; welding.**

assembly language See **computer assembly language.**

assembly, prefit A process for checking the fit of mating detail parts in an assembly prior to final assembly.

assessment, risk See **risk assessment.**

association See **Appendix C, Worldwide Plastics Industry Associations; Appendix D, Worldwide Plastics Industry Events.**

assurance, quality See **quality assurance.**

A-stage See **A-B-C stages.**

Astroturf A trade name for Monsanto's family of nylon textile goods. See **grass, synthetic.**

asymmetric Irregular form. Opposite of symmetrical. Of such form or shape that no point, line, or plane exists whose opposite portions are exactly similar. See **geometry.**

asymmetric carbon atom See **atom carbon, asymmetric.**

asymmetry See **molecular asymmetry; molecular symmetry.**

asymptote A straight line connected with a curve such that as a point moves an infinite distance along the curve from the point to the line it approaches zero and the slope of the curve at the point approaches the slope of the line. See **geometry.**

asynchronous See **fabricating asynchronous.**

atactic molecule See **molecule, atactic stereoisomerism.**

atactic plastic A plastic with molecules in which substituent groups or atoms are arranged at random above and below the backbone chain of atoms, when the latter are arranged all in the same plane. It is the opposite of *stereospecific plastic.* See **molecular structure; stereospecific plastic.**

atactic stereoisomerism See **molecular atactic stereoisomerism.**

atecticity See **molecular atecticity.**

Atlac A trade name for Atlac's family of polyester plastics.

atmosphere (atm) 1. The envelope of gases (air) that surrounds the earth and that exerts pressure on earth. Certain plastic fabricating processes are influenced by this pressure. The atmosphere is comprised of four major divisions: the troposphere (from sea level to about 10 km), the stratosphere (ozone range from 10 to 50 km), the mesosphere (from 50 to 100 km), and the thermosphere (from 100 to 1,000 km or more). No sharp boundaries exist between layers. The pressure exerted at sea level is 14.696 psi (101.325 kPa), which will support a column of mercury (Hg) 760 mm high (about 30 in.) having a density of 13.5951 g/cm^3 at a temperature of 0°C (32°F) and standard gravity of 980.665 cm/s^2. This atm is a standard barometric pressure, though it varies slightly with local meteorological conditions. With changes in elevation, the atmospheric pressure goes down. This pressure is used in fabricating processes where only contact or very low pressure such as vacuum pressure (where atmospheric pressure is applied) is required. Those processes include certain casting systems and reinforced plastic systems. **2.** An environmental gas or mix of gases; an inert atm of nitrogen (N_2), oxygen (O_2), etc. See **air.** See **ablative plastic; barometer, atmospheric; autoclave nitrogen atmosphere; boiling point; calculus; casting; chemical atmospheric bond; distillation, atmospheric;**

gravity acceleration; humidity, atmospheric hygrometer; laboratory atmosphere, standard; packaging, modified-atmosphere; pressure, atmospheric; pressure standard state; reinforced plastic contact molding; smog; torr; volcano; waste, invisible; weatherability; weather condition, factual.

atmosphere, controlled A gaseous environment for conducting tests in which oxygen, carbon dioxide, and nitrogen are held constant at specific test levels and the temperature is controlled.

atmosphere, dry deposition The deposition of materials from the atmosphere without the aid of rain or snow. Particles can be in the range of 2.5 microns as well as pollutant gases (SO_2, NO_2, etc.). See **pollution, air.**

atom The smallest possible unit of an element comprised of a nucleus containing one or more protons and (except hydrogen) two or more neutrons, and one or more electrons that revolve around the nucleus. The protons are positively charged; the neutrons have no charge; the electrons are negatively charged. Atoms of the same or different elements combine to form molecules, which are called *compounds* when the atoms are of two or more different elements. See **atom, isomer; carbon; chemical compound; chemical polymer; element; ion; molecule; nucleus; proton.**

atom, alpha A substituting atom or group in an organic compound. See **beta.**

atom bond, coordinate covalent Also called *dative bond.* A bond in which the pair of electrons is supplied by one of two bonded atoms.

atom bond, multiple A bond in which two atoms share two or three electron pairs. See **acetylene.**

atom, asymmetric carbon A carbon atom to which four different atoms are attached. Asymmetric C-atoms give rise to optical isomerism. See **optical isomerism; polypropylene-butene plastic.**

atom catenation The ability of the atoms of an element to form bonds with one another.

atom, cation A positively charged atom.

atom cell See **cell, unit.**

atom, chelate A five- or six-member ring formation based on intramolecular attraction of hydrogen, oxygen, or nitrogen atoms.

atom coordination number In a crystal lattice, the number of atoms or ions surrounding an atom or ion. In a coordination compound, it is defined as the number of donor atoms surrounding the central metal atom in a complex.

atom covalent bond A bond in which two electrons are shared by two atoms of either the same or different elements.

atom, diamagnetic susceptible See **molecule, diamagnetic susceptible.**

atom donor The atom in a liquid that is bound to the metal.

atom electrovalent bonding A state that occurs when one atom essentially takes electrons away from another atom, with two atoms being converted to ions. These ions have opposite charges and are attracted to each other by the resulting positive-negative attraction. See **covalent bond.**

atom energy state, excited An energy state of a system that is of higher energy than the ground state (lowest energy). The term is usually applied to the energy state of an electron in an atom or molecule.

atom, free-rotation The rotation of atoms, particularly carbon atoms, around a single bond. Because the energy requirement is only a few kcal, the rotation is said to be free if sufficient thermal energy is available.

atom functional group A group of atoms that confers particular characteristics on compounds containing them. Examples include hydroxyl groups of alcohols, carboxyl groups of organic acids, and amino groups of amines.

atom, hydrogen See **hydrogen atom bonding.**

atom, hydroxyl group A combination of one atom of hydrogen and one atom of oxygen (-OH) attached by a single covalent bond to another atom, such as carbon, in a molecule of an organic or inorganic substance. It is a characteristic group of alcohols and hydroxides. Hydroxyl groups on the surface of a material usually make it hydrophilic. Hydroxyl groups are quite reactive; they readily undergo etherification or esterification. Also called *hydroxy group.*

atomic absorption spectroscopy See **spectroscopy, atomic absorption.**

atomic attraction See **polarity.**

atomic, di- Containing two atoms.

atomic mass The mass of an atom in atomic mass units. For an element, the term generally refers to the average mass weight of the naturally occurring mixture of isotopes.

atomic nucleus bombardment The impingement on an atomic nucleus of accelerated particles such as neutrons or deuterons for the purpose of inducing fusion or of creating unstable nuclei that become radioactive.

atomic number The number of protons (positively charged mass units) in the nucleus of an atom on which its structure and properties depend. The number represents the location of an element in the periodic table. See **element; periodic table.**

atomic radial distribution function See **amorphous plastic scatter.**

atomic structure The arrangement of the parts of an atom that consists of a massive, positively charged nucleus surrounded by a cloud of electrons arranged in orbits describable in terms of quantum mechanics. See **molecular structure; Staudinger, Hermann.**

atomic theory The assumption that matter is composed of particles called *atoms* and that these are the smallest subdivisions of matter. See **design; empirical; research and development; theory.**

atomic weight The relative mass of an atom of any element based on a scale in which a specific carbon atom (carbon-12) is assigned a mass value of 12. See **molecular weight.**

atomic influence on properties See **chemical composition and plastic properties.**

atom, isomer A compound, radical, ion, or nuclide that contains the same number of atoms of the same elements but differs in structural arrangement and properties. See **molecular structure; optical isomerism.**
atom, isotope See **isotope.**
atomization See **air atomization; coating, centrifugal atomization; foamed polyurethane.**
atom, radical See **radical.**
atomic structural behavior See **molecular structure configuration.**
atom, transstereoisomer A stereoisomer in which atoms or groups of atoms are arranged on opposite sides of a chain of atoms.
atom twinning A movement of planes of atoms in the lattice parallel to a specific (twinning) plane so that the lattice is divided into two symmetrical parts that are differently oriented. The amount of movement of each plane is proportional to its distance from the twinning plane.
atom, unsaturated A compound that has more than one bond between two adjacent atoms, usually carbon atoms, and is capable of adding other atoms to reduce the bonds to a single bond.
atom, valence shell See **valence shell.**
Attane Dow Chemical's trade name for its family of polyethylene, ultra-low-density plastics.
attenuation **1.** The diminution of vibrations or energy over time or distance. See **vibration. 2.** The process of making thin and slender, as applied to the formation of fiber from molten glass. See **fiberglass production; glass flake. 3.** A decrease in the strength of a signal between two points or between two frequencies.
attribute statistic See **statistical data collection.**
attrition mill See **mill, attrition.**
audio compact disc See **compact disc.**
auditing, quality See **quality auditing.**
autoclave **1.** A closed, strong vessel for conducting chemical reactions under high pressure. See **chemical reaction. 2.** A vessel used to fabricate parts of reinforced plastic molding, adhesive assembly, and so on. See **molding, isotactic. 3.** A vessel used for the sterilization of plastic (and other materials) medical devices, packages, and so on. See **sterilization, heat.**
autoclave molding dwell See **dwell.**
autoclave molding operation A method of providing high temperature and high pressure conditions to process different products. Cure conditions are available that exceed 600°F (316°C) and 500 psi (3.447 MPa). The higher temperatures and pressures are used and required by the high-melt plastics such as polyimide plastic. If still higher curing conditions are required, and the danger of extremely high pressures is to be avoided, a hydroclave can be used. It provides water pressures as high as 10,000 psi (68.9 MPa). A bag is used around the plastics being cured. See **molding, thermal expansion; processing fundamental; reinforced plastic autoclave molding; reinforced plastic, press clave.**
autoclave nitrogen atmosphere A process that provides N_2 on-site to help prevent fires within autoclaves from spreading or becoming explosive when using air. Although they are not common occurrences, fires in autoclaves can be disastrous. Carbon dioxide atmosphere can also be used in the place of N_2; however, CO_2 can be more costly and may initiate unwanted chemical reactions. See **carbon dioxide; cure; nitrogen gas/liquid.**
autoclave thermal expansion molding A process that constrains elastomeric tooling details within a rigid frame to generate consolidation pressure by thermal expansion during the curing cycle of the autoclave molding process. See **molding, thermal expansion.**
autoclave sterilization See **sterilization, heat.**
autoclave venting The process of turning off the vacuum source and venting the bag to the atmosphere after processing plastic materials within a bag requiring a vacuum to initiate proper/uniform pressure (also less entrapped air and/or gasses formed during the process). The pressure on the part is then the difference between pressure in the autoclave and atmosphere. See **air vent; atmosphere; bleed; reinforced plastic bag molding; vent cloth; venting.**
autoflex die See **die, autoflex.**
autogenous, extruder See **extruder, autogenous.**
autoignition point See **combustion, autoignition point.**
automatic control See **control actuator; control, automatic; operation, automatic.**
automatic form, fill, and seal See **blow molding, extruder blow, fill, and seal; medical packaging; thermoforming, form, fill, and seal.**
automation The science and practice of machinery and mechanisms that are so self-controlled that manual input is not necessary during operation. The continuing development of more sophisticated processing equipment in turn allows the development of more integrated processing equipment. Automation improves (1) operating efficiency by reducing scrap and rejects, (2) quality by producing uniform, repeatable manufacturing procedures, (3) decision making and record keeping by converting data to information, (4) communication by providing supervisors and management with access to manufacturing information, and (5) process control and process management. See **art and science; computer automated laboratory to production; motion control system; operation, automatic.**
automation level The degree to which a task or process operates automatically. This degree must take into account the ability of the system to diagnose problems in operation, the ability of the system to recover from error or fault, the ability of a system to start-up and shut-down without human intervention, and the like. See **reliability.**
automation, vision A means to achieve automatic equipment operation by applying adaptive part removal such as during blow molding, injection molding, etc. It provides the capability of detecting a variety of part prob-

lems or defects in critical part inspection. See **inspection; inspection, vision system; troubleshooting.**

automobile bumper fascia The body-colored surface of the automobile bumper that provides good low-temperature impact resistance, low thermal expansion dimensional stability, painted durability, etc. It has replaced the chrome-plated metal bumper surface. The fascia is just one component of the bumper. The bumper system on a modern car might consist of the fascia, energy absorbers, and reinforcing beams. It is estimated that about 85wt% of fascias are made from thermoplastic polyolefins (TPOs) followed by 10% polyurethane, 5% PC/PBT, 1% ionomers, and others. Their thickness has gone from about 3.5 mm to as low as 2.4 mm. See **polyolefin, thermoplastic.**

automobile, composite A car made by using unreinforced or reinforced thermoplastics and thermoset plastics. These cars are designed to produce low-cost purchases, light weights, low fuel costs, and low contaminating emissions. Chrysler Corp.'s lightweight composite concept vehicle (CCV) includes TP structural body panels with only a limited amount of metal underneath; it is an all-plastic body requiring a very large mold. Ford Motor Co. has an all-aluminum body, while General Motors Corp. is focusing on an electric vehicle. Asha/Taisun of Singapore is producing taxi cabs for China with thermoformed body panels mounted on a tubular stainless steel space frame.

Sichuan Huatong Motors Group in Chengdu, China, has produced the all-plastic car called Paradigm, a four-door, five-passenger midsize vehicle. It features a glass-fiber, TS polyester RP sandwich chassis and thermoformed coextruded ABS body panels with molded-in color completely adhesively bonded body and, for the high-end model, a coextruded acrylic (ASA) cap cover providing high gloss. Automotive Design & Composites Ltd. of San Antonio, Texas (United States), has served as the primary contractor for developing the concept. The chassis features a single thermoformed lower tub and an upper skeleton X-brace roof. It employs a monocoque structure where body panels are stitched-bonded to the chassis, forming a unitized structure. Quadraxially oriented (four directional layers) glass-fabric, TS vinyl ester polyester reinforced plastic sheets with a foam core and gel coating are used. Most of the panels are 3 mm thick with molded-in rib structure supports. Body skins are bonded to the chassis with a double-stick acrylic tape developed by 3M Co. as well as mechanical fasteners. Unlike most steel designs, no B-pillar structural component between the front and rear doors is required, thus providing more interior space and easy entry since doors open in opposite directions. Ceramic tooling are used to thermoform plastic parts. Bumper to bumper, it measures 4.6 m (15.18 ft); weighs 815 kg (1,793 lb) including 550 kg (1,200 lb) of plastics; has a gas and electric hybrid power system, air bags, neon tube tail-lamps, etc.; and gets 132 km (60 miles) per gallon of fuel. Huatong and the Chinese government have invested $100 million in this global project.

Europe's plastic-skin, two-seat coupe is called the Smart car and has molded-in color that virtually eliminates painting. The idea was to eliminate the need for three coats of paint and reduce both cost and emission problems. The project started in 1994 via a joint venture of Daimler-Benz in Stuttgart, Germany (then known as Mercedes-Benz) and the Swiss watchmaker SMH AG in Biel. They created a new company called Micro Compact Car AG, or MCC. The first of the cars had plastic injection-molded outer body panels using GE's PC/TP polyester blend (Xenoy). Its unitized TP body ties together the front fender, outer door panels, front panels, rear valence panels, and wheel arch in one wrap-around package. The entire car weighs 1,440 lb (650 kg), about 600 lb (270 kg) less than most steel-body compacts. See **automobile, DeLorean; automotive market, number of automobiles; composite; design, geodesic; design monocoque structure; fastener; injection molding; quality system QS-9000; reinforced plastic; thermoforming.**

automobile, DeLorean An early innovative car identified as the DMC-12 weighing 2,200 lb (1,000 kg) and using 600 lb (273 kg) of unreinforced and reinforced plastics.

automobile spring See **design spring.**

automobile steel recycling See **recycle steel with vinyl scrap.**

automotive intake manifold An intake device capable of making multiple connections. Worldwide plastic intake manifold production processes of about 11 million units annually are 45% soluble core molding, 32% welding, 10% injection molded, 5% snap-fit, 2% blow molded, and 6% others. See **blow molding; design, snap-fit; injection molding; soluble core molding; welding.**

automotive interior, low-emission plastic A plastic that causes low levels of pollution. Air pollution in the interior of autos that is not caused by exterior air can give rise to complaints by passengers. The contaminants usually discussed are in the ppb region (parts per billion, corresponding to $\mu g/m^3$). On this scale, contamination is commonly referred to as *traces*. Many different tests exist to detect contaminants, including odor and fogging tests. The target has been to use plastics with none or the permissible tolerance of low-volatile components that are released from certain plastics, such as plasticized polyvinyl chloride plastic. See **odor; solvent; plasticizer.**

automotive market A vital area of transportation technology in which plastics provide special design considerations, process freedom, novel opportunities, economy, and so on. The lightweight and low-cost principally injection-molded thermoplastic car body can totally eliminate the metal structure once needed to support body panels. Pickup trucks use 100 lb thermoformed cargo-bed liners. With more fuel-efficiency regulations new developments in lightweight vehicles are occurring with plastics and aluminum benefiting. Plastics used include primarily ABS, TPO, PC, PC/ABS, PVC, PVC/ABS, PUR, and RPs. See **tanker truck, reinforced plastic; transportation market; truck and plastic; waste.**

automotive vehicle size See **plastic industry size.**

automotive plastic engine Since the 1950s, plastic engines, with heat shields such as metal or special heat-resistant plastics, have been shown to have performance advantages such as lighter weight. However, they were too costly. For many decades, reinforced plastics have been extensively used in engines and other parts of racing cars, principally to reduce weight. See **reinforced plastic.**

automotive risk See **risk, acceptable.**

automotive seat The third most expensive system in the car, after engines and transmissions. Seating involves diverse technologies, a wide range of materials (plastics, etc.), and high labor content.

autothermal extruder See **extruder, adiabatic.**

auxiliary equipment (AE) Auxiliary equipment of many different types supports production in-line systems and the secondary operations (SO) that are used to maximize overall processing productivity and efficiency and to reduce cost. Primary processing operations are the basic equipment (extruder, injection molding, mold). Cost of the upstream and downstream (of the main in-line equipment) AE can sometimes be more than the primary equipment. Requirements for AE are based on reliability and production-line needs. It is important to properly determine requirements and ensure that the AE interface into the line (size, capacity, speed) to avoid costly problems. AE has become more energy-efficient, reliable, and cost-effective. The application of microprocessor- and computer-compatible controls that can communicate with the line (train) results in pinpoint control of the line. Rules have been developed for communication protocol and transfer of data between primary and auxiliary equipment. With polychlorofluorocarbon used in equipment such as chillers and refrigerations, it is important to keep up to date on the phasing out of PCFCs. Examples of AE include adhesive applicators, chillers, coolers, cutting devices, dicers, dies, dryers, dust collectors, freezers, granulators, grinders, heaters, material handlers, mixers, ovens, printers, process controls, railcar unloaders, robots, trimming devices, welders, and many more. Also called *secondary equipment.* See **assembly; bottle weight controller; chiller; communication protocol; computer software; control actuator; controller; control system reliability; converting equipment; designing plant layout by computer; device, smart; energy conservation; fabricating processing type; fabricating startup and shutdown; fabricating turnkey operation; material handling; numerical control; operation, automatic; operation, manual; operation, secondary; operation, semiautomatic; plastic consumption machine sales; polychlorofluorocarbon; reliability; safety machine lockout; troubleshooting by remote control.**

auxiliary equipment, interrelating See **World of Plastics Reviews: The Plastics Industry: All Sectors, Including Machinery and Equipment.**

average deviation See **mean absolute deviation.**

Avogadro's law The rule that equal volumes of the same or different gases under the same conditions of pressure and temperature contain the same number of molecules. See **gas; kinetic theory; molecular structure.**

axial winding See **filament winding, axial.**

Azdel A trade name for GE's family of stampable reinforced thermoplastics.

azodicarbonadide (AZ) A blowing agent. See **foam and blowing agent.**

B

back-flash The rapid combustion of material in an area that the reaction was not intended to occur. See **safety and machines.**
back-flow stop valve See **screw tip, injection.**
backlash The space between gear teeth. This space must be larger than the gear teeth width as measured on its pitch circle to avoid jamming the gears. See **accuracy; extruder drive backlash; extruder gear box; gear; repeatability.**
backlog The accumulation of customer orders that have not yet been processed expressed in sales dollars or hours of production time. See **business bookkeeping; purchase order.**
back molding See **injection molding, back molding.**
back pressure **1.** The resistance of plastic melts to continued flow during processing, determined by viscosity. **2.** The upstream line pressure caused by a restrictive device, such as a mixing head. **3.** The pressure created when the injection molding or extruder melt resists the forward movement of the melt in the plasticator and causes the material to have a high mixing action. Controlling back pressure can improve plastic melting action, color dispersion, and output quality and rate. See **extruder; injection molding; plasticator.**
backrinding See **vulcanizate backrinding.**
back taper See **mold undercut.**
bacteria One-cell microorganisms having a wide range of biochemical properties. They are present in almost all natural environments. Billions of these microorganisms occur in a gram of rich garden soil; millions in a drop of saliva. Although some bacteria cause disease, most are benign, and many are involved in processes beneficial to humans and plastics. See **antimicrobial agent; biodegradable waste; deodorant additive; environment; landfill and degradation.**
bacteria, aerobic Single-cell, microscopic organisms that need oxygen to survive. Some aerobics are important in breaking down solid waste into simple compounds. See **waste.**
bactericide A substance used in small percentages to kill bacteria that may occur in liquid adhesive forms or that may attack carbohydrate or proteinaceous films. See **adhesive; film.**
bacteriostat See **degradable.**
bad plastic See **plastic advantages and disadvantages; plastic myth and fact.**
Baekeland, Leo Hendrik A scientist born in Ghent, Belgium (1863–1944), who did early work in photographic chemistry and invented Velox paper (1893). After moving to the United States, he discovered the phenol-formaldehyde plastic originally called Bakelite (1909). Baekeland was first to learn how to control the reaction of phenol and formaldehyde (which had been investigated by Bayer in 1872) to yield dependable results on a commercial scale. The Bakelite Co. was founded in 1910; it latter became a division of Union Carbide and continued to change ownership. See **Bakelite; phenolic plastic.**
baffle **1.** In general, a device used to restrict or divert the passage of fluid through a pipeline or channel. **2.** In hydraulic systems, the device, which often consists of a disk with a small central perforation, that restricts the flow of hydraulic fluid in a high-pressure line. **3.** When applied to tools such as molds, a plug or similar device located in the mold's water channel. It is designed to divert or restrict the flow to a desired path. It also aids in developing a turbulent flow of the fluid to remove heat from the plastic at the required uniform rate and in the shortest time period. See **mold cooling; Reynold's number.**
bag, See **additive, slip; dust collection, bag filter; dust collection, bag-house; extruder blown film-bag manufacturing; filament winding frequency and bag molding; landfill and degradation packaging, bag-in-box; prepackaging, grocery-bag; reinforced plastic bag molding; test, bag-drop impact; vinyl seagoing bag; waste, plastic-bag.**
bag gusset The part design that incorporates an angle of material to support or strengthen adjoining sections of a part. A tuck in each side of the bag is used. These gussets enable the completed bag to be opened out into a three-dimensional rectangular form when filled. Gussets can be produced in-line, such as during extruding blown film. See **extruder blown film-bag manufacturing.**
bag, self-opening style (SOS) A common bag shape.
Bakelite The proprietary name used indiscriminately to describe a phenolic material or part. See **Baekeland, Leo Hendrik.**
baking finish See **finish, baking.**
balanced construction See **directional property, balanced.**
balanced runner See **mold runner.**
balanced twist See **yarn twist, balanced.**
baling See **material handling baling.**
ball-and-socket joint See **injection molding, two-shot.**
Ballatini process See **extruder back pressure relief port.**
ball burst test See **test, ball-burst film impact.**
ball-check valve See **screw-tip check valve.**
balloon effect, melt See **mold-cavity melt fountain flow.**
balsam plastic A natural plastic made from the balsam fir *Abies balsamea.* Dissolved in zylene, toluene, or ben-

zene, it is used for permanent microscopical preparations. Its refractive index may vary from 1.530 to 1.545, and its softening point from room temperature to 100°C (212°F); these properties vary with age and solvent content. If impure, it discolors with age. See **oleo plastic.**

balsa wood See **wood, balsa.**

bamboo A grass or plant native to Southeast Asia having a high cellulose content and offering extremely high performance. It is used in the manufacture of specialty papers, light fixtures, fishing rods, and building scaffolds. The development of the composite system is based on the growth concept of the natural composite bamboo (which is still being used as a building material in Asia). Bamboo stalks receive their high specific strength and modulus of elasticity from unidirectional-oriented cellulose fibers that are embedded in a matrix of lignin and silicic acid. Although a similar situation exists in wood, the fibers in wood are usually 1 mm long, whereas in bamboo they reach up to 10 mm. The hollow bamboo stalks are stabilized by evenly spaced flat, strong nodes rectangular to the longitudinal axes. See **directional property, uniaxial load; modulus of elasticity.**

bambooing melt See **extruder melt bambooing; melt fracture.**

banbury mixer See **mixer, banbury.**

bank In equipment such as a calender, mill, mixer, or spreader, a reservoir of plastic at the opening of the equipment, such as between two rolls (where they kiss) or at a spreader bar. See **calender; extruder roll coating, kiss; mill; mixer; spreader.**

bar See **pressure, bar.**

barcode The electronic, optical bar-recognition system used for identification, storage, printout, and retrieval of specified data and information that pertain to many of the materials, equipment, products, etc. used in the fabricating plant. It first was used in the late 1940s. Plastic parts are used extensively in producing barcodes. See **European Article Number system; laser marking; material handling; plant operation; printing, screen.**

Barcol hardness See **test, Barcol hardness.**

bare glass See **fiberglass, bare.**

Barex The trade name for BP Chemical International's (Sohia Division) family of acrylonitrile (AN) copolymerized styrene plastic. It was the first technically and commercially successful carbonated beverage bottle to be produced and was used in producing the first Coca-Cola stretched injection blow-molded bottles. See **Coca-Cola bottle.**

barium oxide (BaO) A white to yellow powder that melts at 192°C. It forms a hydroxide with water and is used as a dehydrating agent. Also called *barium monoxide* or *barium protoxide.*

barium stearate A white, crystalline solid with a melting point of 160°C. It is used in plastics as a stabilizer against deterioration caused by heat and light, as a lubricant in fabricating plastic and rubber products, etc. See **light stabilizer; stabilizer.**

barometer, atmospheric An instrument used to measure atmosphere pressure.

barometric pressure See **atmosphere.**

barrel **1.** A cylinder that contains a screw. It provides the bearing surface where shear is imparted to the plastic granules. Heating and cooling media are housed around it to keep the barrel (melt) at the desired temperatures. Sizes are classified by the barrel's inside diameter (ID) and overall length. It is common practice to refer to the barrel length/diameter (L/D) ratio. Also called *cylinder* or *plasticator barrel.* See **screw. 2.** A container used to perform different tasks in processing plastics, such as mixing compounds or agitating by rotation or vibration to remove flash and sharp edges from moldings. See **heat-transfer mechanism; mill; mixer; trim.**

barrel alignment A maintenance check to ensure the screw, die, mold, and any auxiliary equipment attached to the barrel are all aligned. See **barrel borescoping; machine alignment.**

barrel and feed unit The feed throat is the section in a barrel where plastic is directed into the screw channel. It is fitted around the first few flights of the screw. In machines that do not have a separate feed throat, the feed throat is an integral part of the barrel, which may not be the best design approach. The feed-throat and feed-hopper units are important in ensuring that plastics are properly plasticized. A plasticator's feed-throat size and shape can have a significant affect on output and stability. In general, the smaller the hole, the more adverse the effect. Sometimes smaller feed holes can be compensated for by screw designs, but more often the feed-hole geometry must be modified. Output rates have been observed to vary as much as 25% with the only variable being the feed-throat geometry. Round feed throats are sufficient for 100% pellet feed, but when 20% or more regrind is added with the virgin feed, rate is reduced; a rectangular or oblong opening will improve the feeding characteristics. An elongated opening also helps in eliminating potential bridging problems in the throat. Some materials, such as flakes and regrind, have poor flow so they present their own problems that can be resolved.

barrel and feed-unit heat control The feed-throat casting is generally water-cooled to prevent an early temperature rise of the plastics. A good starting point is to have the temperature about 110°F to 120°F (43°C to 49°C) or warm to the touch to help ensure that a stable feed is developed. If the temperature rises too high, it may cause the plastic to adhere to the surface of the feed opening, causing a material-conveying problem to the screw. The overheated plastic solidifies at the base of the hopper or above the barrel bore, causing bridging that prevents material from entering the screw. The problem can also develop on the screw, with plastic sticking to it and restrict forward movement of material. Overcooling the hopper can have a negative effect on extruder performance due to a heat sink effect that pulls most of the heat from the feed zone of the barrel. Because hopper-block cooling primarily prevents sticking or bridging in that area, it should not be run colder than necessary. Always control water flow in the throat-cooling systems from the outlet side to prevent steam flashing and to minimize air pockets.

barrel and feed-unit operation To maintain the maximum and most consistent feeding, it is necessary to exercise care when changing hopper dimensions, changing feed-throat openings, or adding any intermediate sections (side feeders, magnet packs, adapters, etc.). When reengineering the solids delivery system, consider the following information: (1) the minimum taper for hoppers is 60° for general-purpose use, with some plastics requiring a smaller angle and steeper sides; (2) the system needs to be streamlined with no ledges, projections, or rough surfaces; (3) as much as possible, changes in shape, such as round to square, need to be avoided because each change of shape causes a restriction to flow; (4) the absolute minimum cross-section in any solid's flow channel should be the cross-section of the barrel bore, with a preference of about 1½ times the cross-section of the barrel bore. In effect, solids flow much like liquid flow: anything that has entry problems, is not streamlined, has shape changes, or has a restrictive flow area will result in excessive pressure drops. Unless there is a minimum pressure of the solid's mass at the entry to the screw, the screw channel will not fully fill. This is particularly true as the screw speed increases and obviously varies with the characteristics of the solids. See **feeder.**

barrel and feed-unit operation protection The hopper can be fitted with devices to perform different functions. For example, hoppers can be fitted with a hinged or tightly fitted sliding cover and a magnetic screen for protection against moisture pickup and metal ingress, respectively. A hopper drier, especially useful when processing certain materials such as regrind and colors, can be of value in limiting material handling as well as removing moisture. See **safety; troubleshooting.**

barrel and screw wear See **barrel wear; screw and barrel wear.**

barrel bell end A flange at the discharge end of the barrel that provides added strength for withstanding internal pressure.

barrel bore See **bore.**

barrel borescoping The alignment of a barrel with the screw. Clearance can range from 0.05 to 0.20 mm (for small- to large-diameter screws) on any side of the screw. Borescoping does not guarantee that all problems will be corrected. With an alignment scope, one can tell what the internal shape of a barrel is at any point—whether straight, curved, or even S shaped, which may be due to machining or wear. Aligning with a scope helps produce better products with less downtime and less scrap and helps extend the life of the barrel and screw. Most machines can be adjusted in a day at very little cost and will have its life extended by at least 25%. For example, if a barrel costs $12,000 and a screw $9,000 for a total of $21,000, extending their life only 25% saves over $5250, not counting increased production. See **screw inspection.**

barrel bridging See **screw and barrel bridging.**

barrel burnishing See **burnish.**

barrel C-clamp flange A circular tapered flange at the discharge end of an extruder barrel used to hold the die adapter. A similar-shaped flange on the die adapter and a C-shaped clamp accomplish the closure.

barrel composition Various metal compositions that are used to meet different barrel requirements principally based on the plastic being processed. Popular are nitrided and bimetallic abrasion-resistant barrels. Some barrels have insert sleeves requiring precision manufacture. The barrels can extend the working life of their sleeves by reducing abrasion and increasing corrosion resistance. The chemical compositions produce alloys and blends with boron, chromium, cobalt, manganese, nickel, silicon, and tungsten. The actual chemistry may vary widely after final machining is complete. The chemistry and hardness are not necessarily indicative of wear resistance. Other important factors are how these elements are combined and where they are located relative to the bore. See **barrel wear; nitriding; screw material; screw mechanical requirement.**

barrel control temperature See **temperature controller.**

barrel control transducer A device that is inserted in different zones of the barrel to sense melt condition. Thermocouple and pressure transducers require accuracy in proper locations and recording instrumentation. See **transducer.**

barrel cooling A method of maintaining optimum barrel temperature. Different methods are used, such as liquid cooling channels, coils around the barrel, and forced air around the usual extruder barrel's fins (which provide more cooling surfaces). See **coolant; mold water channel.**

barrel dimension and tolerance The optimum size and condition of a barrel. For extrusion and injection molding machines, the SPI's Machinery Component Manufacturers Division has guidelines that should be consulted on receiving or replacing machines with barrels. Barrels should be measured before use to determine whether any wear or damage occurs after they are put into operation.

barrel downsizing and upsizing The adjustment of barrel size according to processing needs. Machines are designed to process certain quantities of different plastics at certain rates. Problems can develop with excessive residence time, particularly for the engineered plastics. Instead of replacing the entire machine, the barrel system is changed (it is best to start with the properly sized machine). Downsizing, usually to a limited amount with plasticators, requires a smaller screw, smaller heaters, modification of the barrel shroud, etc. Upsizing, which is rare, to increase output will reduce the available pressure and set up torque limitations on the larger screw. See **injection molding machine downsizing; injection-molding machine upsizing.**

barrel; extruder and injection-molding An extruder barrel differs from an injection-molding (IM) barrel in several ways. It is usually longer, with minimum length-to-diameter ratio of 24 and a maximum of at least 36. The IM is usually 18 or 20, with possibly a few at 24. Some vented barrels are 32, but the trend is toward shorter lengths. The extruder barrel is usually designed to withstand lower melt pressures of 10,000 psi (69 Mpa); the IM is up to 20,000 psi (138 MPa) as the usual standard and can go up to 30,000 (207 MPa). This means a thinner wall and eliminates the high-pressure sleeve or bell end. The extruder barrel connects to the die adapter, but the seal is made slightly different. It has a female counterbore, just like the IM, but the die adapter has a recess for a rapid removal breaker plate. See **extruder; injection molding.**

barrel fail-safe rupture disc A disc that opens to relieve barrel pressure, if pressure exceeds its rate burst pressure. See **plasticator safety; safety.**

barrel feed hopper See **feed hopper.**

barrel feed housing A component of the plasticator barrel that contains the feed opening, water heating or cooling channels, and, in certain units, barrel grooving to improve flow of plastics into the screw flights. If required, particularly in extruders, a thermal barrier is used where it is attached to the barrel. See **feeder.**

barrel finishing See **finishing, barrel.**

barrel flange, front A flange at the downstream or discharge end of an extruder barrel to which the die or adapting member is attached. In an injection-molding machine, the flange provides a means to attach the machine's nozzle. See **extruder barrel adapter.**

barrel grooved feed A feed section in which the internal barrel surface is grooved. Particularly for certain materials, the grooves permit considerably more friction between the solid plastic particles and the barrel surface, resulting in an increase in process output and an improvement in process stability. See **accuracy; repeatability.**

barrel heater A heat source for plastic in the barrel that is usually zoned so that a controlled temperature profile is developed to meet melt requirements. See **heater band.**

barrel heater zone The electrical resistance or induction heaters that are mounted on or around the barrel in different locations along its axis. For a short barrel, usually only one zone is used. The longer barrels have two or more zones that permit individually controlled heating zones, which produce the required melt temperature as the melt travels through the barrel.

barrel history Barrels originally were used for extruding natural rubber. They were made of nitrided steel or special steel alloys with a very high chromium content and had a one-piece design. The trend continues toward bimetallic barrels. The Industrial Research Laboratory developed Xaloy 100, the first bimetallic, in 1939. It was a centrifugally cast, abrasion-resistant liner material inside an alloy steel outer shell. These bimetallic liners were originally used as mud pump liners in the oil fields. This type liner is available from different sources worldwide.

barreling See **deflashing; trim; tumbling.**

barrel, injection-molding See **barrel extrusion and injection molding.**

barrel inspection The process of checking different parts of the barrel to meet tolerance requirements (usually set up by the manufacturer) and to determine whether any wear has occurred on the inside diameter, in straightness and concentricity, and to the surface condition. See **concentricity; screw inspection.**

barrel inventory The amount of plastic contained in the plasticator barrel.

barrel jacket A covering that surrounds the outside of a barrel to allow circulation of a heat-transfer medium.

barrel length-to-diameter (D) ratio The relative size of two dimensions of the barrel. Two different approaches are used—with or without the feed opening. The ratio is the difference from the forward edge (or rear edge) of the feed opening to the forward end of the barrel bore divided by the barrel bore. Different variables are involved in multiscrew machines, and so they are generally sized according to the output rate (kg/h or lb/h). See **extruder, multiple-screw; extruder, single-screw; screw length-to-diameter ratio.**

barrel liner, grooved A liner whose bore is provided with longitudinal grooves to enhance plastic melt flow.

barrel-liner sleeve A cylindrical housing in which the screw rotates, which permits replacement when wear occurs.

barrel material See **barrel composition.**

barrel pilot A cylindrical portion at the barrel's rear end that is used to locate the barrel with the feed throat.

barrel protection A ring made to fit the exposed edge of the bimetallic liner, which can be easily damaged when the screw is inserted.

barrel purging See **purging.**

barrel repair See **barrel wear; screw rebuilding and repair.**

barrel and screw bridging See **screw and barrel bridging.**

barrel temperature See **melt-temperature effectiveness; screw temperature zone; temperature controller.**

barrel venting See **injection molding, venting; screw decompression zone, venting; screw, venting; vent bleed.**

barrel-venting safety Precautions taken to avoid having a plugged vented barrel (that is being used in the same way as a solid parallel machine) develop internal barrel pressure that exceeds the strength limit of the bolts retaining the plug and that violently releases the plug from the barrel. One safety precaution is to use retaining bolts that have more than enough strength. Another is to rotate the barrel downward or away from the operator (even when no plug is used, in case the vent opening becomes overloaded with melt that is forced out). A pressure gauge at the head of the barrel can provide a preliminary warning at minimum safety pressure and can shut off the machine at higher pressures or otherwise alert all in the plant. Shear pins or a rupture disk can be installed. In addition, the machine can be heated adequately at the forward barrel end. See **plasticator safety; safety; venting; venting purifier.**

barrel wear Gradual damage to the surface of the barrel. Most barrels are made with nitrided steel or one of several types of bimetallic construction. Nitriding is a surface-hardening technique that achieves a maximum effective depth of less than 0.4 mm (0.016 in.). Once that thin surface layer is worn away and the steel substrate is exposed, the barrel's abrasive wear resistance is essentially poor. Bimetallic barrels combine a structural steel exterior with an alloy inlay or a tool steel or alloy lining to improve resistance to abrasion and corrosion. In contrast to nitrided steel, bimetallic linings are uniformly hard throughout their depth. Depths are typically about 1.5 mm (0.060 in.) for centrifugal cast linings and about 6.3 mm (0.250 in.) for tool steel or alloy linings. Bimetallic barrels are far more durable than nitrided barrels. The main types of bimetallic barrels are tungsten carbide composites, chromium-modified iron-boron alloys, and nickel alloys. See **barrel composition; screw and barrel wear; screw rebuilding and repair; screw wear.**

barrel wobble See **plasticator wobble.**

barrier A material or device that limits, by physical or chemical means, passage of solids, liquids, semisolids, gases, forms of energy (such as ultraviolet light), or other material. See **aluminum foil; membrane; permeability; water-vapor resistivity; water-vapor transmission.**

barrier chemical treatment See **fluorination; gasoline tank permeability; sulfonation.**

barrier foil See **aluminum foil.**

barrier, glass-coating A process for depositing silica vacuum coatings on plastics. For example, an optical clear, flexible, amorphous silica coating that is 0.2 to 0.5 microns thick can be deposited on certain plastics such as polyethylene terephthalate, polyethylene, or polycarbonate bottles to provide an oxygen barrier comparable to metallized film. See **surface treatment.**

barrier layer A separate layer of material, such as a plastic or metal film, which stops or hinders the passage of another material. See **aluminum foil; barrier plastic.**

barrier, moisture A material that is impervious to water or water vapor. Effective barriers include high polymers such as polyvinyl chloride, polyethylene, and polyethylene-vinyl chloride plastics.

barrier permeability coefficient See **coefficient of gas permeability; coefficient of permeability.**

barrier plastic A plastic material that has low or no permeability to different products. Barrier technology is influenced by performance factors such as chemical composition, cross-linking modification, molecular orientation, density, thickness, and lack of pinholes. Composite (coextruded, coinjected, laminated, or coated) films are often used to reduce permeability while retaining other desirable properties. Total protection against vapor transmission by a single barrier material increases linearly with increasing thickness but usually is not economical. Extensive use is made of multiple-layer constructions that include low-cost as well as recycled plastics to provide mechanical support while significantly reducing expensive barrier material thickness.

With crystalline plastics, the crystallites can be considered impermeable. The higher the degree of crystallinity, the lower the permeability to gases and vapors. The permeability of an amorphous plastic that is below or not too far above its glass transition temperature (T_g) is dependent on the degree of molecular orientation. It is normally reduced when compared to higher temperatures, although small strains sometimes increase the permeability of certain plastics. The orientation of elastomers well above their T_g has relatively less effect on overall transport properties. Cross-linking thermoplastics decreases permeability due to the decrease in their diffusion coefficient. The effect of cross-linking is more pronounced for large-molecule-size vapors. The addition of a plasticizer usually increases the rates of vapor diffusion and permeation.

The permeation of vapors includes two basic processes—the sorption and diffusion of vapors in the plastic. In the packaging industry, the resistance of wrapping materials to moisture—their vapor-barrier characteristics—is essential for the preservation of many products. The loss of moisture, flavor, and so on through packaging materials may damage foodstuff. However, the prevention of the ingress of moisture by a barrier is essential for the storage of dry foods and other products. In other applications, the degree of resistance to water and oxygen is important for the development of corrosion-resistant coatings, electrical and electronic parts, and so on. Also called *barrier layer.* See **amorphous plastic; coating, oxygen-barrier removable; coefficient of gas permeability; coefficient of permeability; coextrusion tie-layer; coinjection molding; cross-linking; crystalline plastic; diffusion; fluorination; glass transition temperature; ketchup bottle; packaging, film breathable; packaging, food; packaging, modified-atmosphere; penetrant; permeability; polyethylene-vinyl alcohol plastic; polyolefin plastomer plastic; polyvinylidene chloride plastic; sulfonation; surface treatment; test, oxygen gas transmission rate; test, water-vapor transmission rate; tube, collapsible squeeze; water vapor retarder.**

barrier screw See **screw barrier.**

barrier, vapor The barrier properties of materials (plastics, foils, papers, and so on) against various vapors and liquids that are expressed in the form of permeability constants of the materials to the penetrants. The permeation of vapors include two basic processes—the sorption and diffusion of vapors in the plastic. See barrier plastic; **diffusion; sorption.**

barrier via chemical modification A chemical modification of the plastic surface during or after fabrication that permits controlled permeation behavior in certain parts, such as films, diaphragms, and containers. See **chemical composition and plastic property; fluorination; sulfonation; surface CASING.**

base A chemical species, ionic or molecular, that is capable of accepting or receiving a proton (hydrogen ion) from another substance. The other substance acts as an acid in giving the proton; the hydroxyl ion is a base.

base-plastic melt index See **test, melt-flow; test, melt-index.**

base quantity See **percentage point.**

basic Of a chemical species that has the properties of a base.

basic (OH) group A chemical group, such as oxygen-hydrogen, that when freed by ionization in solution produces a pH greater than 7. See **pH.**

basket weave See **fabric, basket-woven.**

bat See **fiber mat.**

batch See **compound, batch.**

batch distillation See **distillation, batch.**

batch mixing See **mixer, batch.**

B-basis The B mechanical property value. The value above which at least 90% of the population of values is expected to fall, with a confidence level of 95%. See **A-basis; population confidence interval; S-basis; typical basis.**

beading **1.** Plastic joining (such as bending an edge, flanging the end of a pipe, and so on) using devices such as rolls with or without heating. **2.** In extrusion lines, a heavy accumulation of the plastic on the edges of film, sheet, or coating. See **extruder neck-in and beading.**

beading, water See **water beading.**

bead molding See **expandable plastic.**

bead sealing See **sealing, heat.**

bearing A device that supports and reduces function between moving and fixed parts. Self-lubricating molded plastic bearings are used in place of metal bearings in bushings, flanges, thrust-shaft configurations, and so on. Different plastics are used to meet different performance requirements (such as the popular nylon and acetal plastics), and additives (such as silicone fluid additives) permit or extend certain plastics use. Some are used as replacements for gauge and needle bearings. Plastics behave differently than metals, with each having their area of interests and performances. See **screw thrust bearing; silicone fluid additive; wear.**

bearing area The diameter of the hole times the thickness of the material.

bearing strength The bearing stress at that point on the stress-strain curve where the tangent is equal to the bearing stress divided by the hole diameter. See **modulus, tangent; stress-strain curve.**

bearing-strength test See **test, bearing-strength.**

bearing stress The applied load lb (kg) divided by the bearing area. See **stress.**

bearing yield strength The bearing strength when material exhibits a specified limiting deviation from the proportionality of the bearing stress to shearing strain. See **shear strain; stress.**

beauty aid See **cosmetic market.**

becquerel See **radionuclide decaying activity.**

beer bottle A bioriented stretched plastic bottle for beer. In the United States, beer-bottle technology will soon include coinjection or coextruded plastics such as polyethylene teraphthalate or polyethylene naphthalate with various barrier plastics such as EVOH or nylon, and coating of LCP to protect taste and extend shelf life. Coor's is testing stretched blow-molded bottles for beer. See **blow molding, stretched; bottle; coating, oxygen-barrier removable; coextrusion; coinjection molding; Coor's beer bottle; polyethylene terephthalate plastic.**

BEES software See **vinyl composition tile.**

beeswax An ingredient that is obtained from bees' honeycombs and is used for many polishing and finishing mixtures. See **carnauba wax; finishing, ashing and lapping; paraffin wax; wax.**

bellow design See **design bottle, collapsible.**

belting Elastomers, unreinforced or reinforced, that are used to meet many different requirements for transmitting power or conveying material. Extrusion and coating are the main processes used in their manufacture. This continuous band of flexible, tough material is composed of the cover and the reinforcement or carcass. The reinforcement is the working tension component, which is protected from the environment by the cover. The top cover is usually thicker than the bottom cover because the greatest wear is concentrated on the top carrying load.

benchmark A mark of known separation applied to a product or test specimen. On a tensile test specimen with a load being applied, a benchmark is used to measure the material extension that is the strain occurring during the test. See **strain; tensile testing machine.**

benchmark interface format See **computer picture-level benchmark.**

bend angle A measure of bendability where the angle through which a plastic is bent under specified loading conditions in a standard bend test. See **bend test.**

bend, free The bend obtained by applying forces to the ends of a specimen or substance without the application of force at the point of maximum bending. See **flexural property.**

bending, extensional See **reinforced-plastic extensional-bending coupling.**

bending laminate See **laminate, high-pressure formable.**

bending strength See **flexural strength.**
bend, radius of The radius of a cylindrical surface of a mandrel that comes in contact with the inside surface of the bend during bending. With free or semiguided bends to 180° in which a shim or block is used, the radius of bend is one-half the thickness of the shim or block. See **filament winding; postforming.**
bend test A ductility test performed by bending or folding, usually by steadily applied forces but in some instances by blows.
bend test, cold See **test, cold-bend.**
Bennett (Bob) test See **test, NOL ring.**
bent section A ridge designed into a formed part that can unfold somewhat to absorb most of the stress when the part is placed under tension.
benzene ring See **chemical benzene ring.**
benzimidazolyl See **optical brightener agent.**
benzoyl peroxide See **catalyst, benzoyl peroxide.**
beryllium copper (BeCu) An alloy that is used in molds to provide relatively fast heat transfer. The two basic families of BeCu alloy are those with high heat conductivity and those with high strength. Its heat conductivity is about 10 times greater than the conductivity of stainless steels and tool steels and double that of aluminum, such as alloy 7075. It has higher hardness and strength than aluminum. See **machining safety; metal, light.**
beta (β) See **atom, alpha.**
beta gauge sensor See **sensor, beta gauge.**
beta particle See **radioactive beta particle.**
beverage can See **packaging, beverage-can.**
bezel A grooved rim or flange.
bias See **error, bias.**
bias fabric See **fabric, bias-woven.**
biaxial flexural strength See **flexural strength, biaxial.**
biaxial properties See **directional property, biaxial.**
biaxial orientation See **orientation, biaxial.**
biaxial winding See **filament winding, biaxial.**
bicyclic See **chemical, bicyclic.**
bifunctional See **molecule, bifunctional.**
billet See **material, billet.**
billow forming See **thermoforming, billow.**
binary See **computer database binary.**
binder **1.** A substance that causes cohesion in loosely assembled substances, such as plastic molding compounds. See **compounding; latex.** **2.** In reinforced plastics, the continuous phase that holds together the reinforcement. See **fiberglass binder/sizing coupling agent; lignin.** **3.** A component of an adhesive composition that is primarily responsible for the adhesive forces that hold two bodies together. See **adhesive.** **4.** See **additive; extender; filler; mixing; wood composition board.**
bingham body See **viscosity, Newtonian flow, bingham body.**
bioabsorbable See **medical absorbable technology.**
bioburden recovery See **sterilization quality assurance.**
biochemistry See **chemistry, bio-.**
biocide An antimicrobial agent added to plastics to protect them from microorganisms. Natural and synthetic plastics are subject to attack by biological agents, and active chemical compounds are used as preservatives to control degradation by living organisms. Those that produce death are called *biocides.* Plastics such as polyolefins, polyesters, or vinyls are considered to be resistant to biological attack. See **cuprous oxide; degradable; plastic, neat.**
biocompatibility Having minimal interaction with the environment; originally, inertness toward the physiological environment. Plastic biomaterials are composed of mixtures of chemicals, some of which are bound to the plastic backbone or into the material matrix. Others are free to migrate into the surrounding environment. The identities and abundance of these chemicals determine the material's biocompatibility. Materials can yield extractables such as antioxidants, lubricants, stabilizers, plasticizers, contaminants, and monomers. See **hemocompatibility; ISO-10993 certification; medical material and environment; test, carcinogenicity; test, medical-device compatibility.**
biodegradable Having the capability of decomposing in the most common environment where it is disposed within a time period such as one year, through natural biological processes, into nontoxic carbonaceous soil, water, or carbon dioxide. Biodegradable plastics are useful in medical products (sutures, surgical implants), controlled-release formulations (drugs, agricultural chemicals) and agricultural mulch that performs when degraded by sunlight or rainwater. See **antimicrobial agent; bacteria, aerobic; biodegradable waste; degradable; deodorant additive; design biomedical product; environment; landfill and degradation; polylactide plastic; starch degradable.**
biodegradable hybrid plant growth See **polyhydroxybutyrate plastic.**
biodegradable paper See **landfill and degradation; recycled paper.**
biodegradable, pseudo See **biodegradable type.**
biodegradable types Completely biodegradable plastics and pseudobiodegradable types of plastics. The latter category includes products that compost in a biologically active environment because they contain, for instance, decomposable starch molecules but that are not completely degradable. Those that decompose completely are considered completely degradable, affording carbon dioxide, water, and biomass, as well as their naturally occurring metabolic products. Compost that is obtained from pseudobiodegradable plastics contains invisible plastic powder that is spread on fields. Such plastics that are "milled" continue to exist for decades, while completely biodegradable plastics reenter the natural, earthly cycle.
biodegradable versus photodegradable The biode-

gradable (BD) additive used in a compound usually causes an 8% to 15% cost increase, photodegradable (PD), a 2% to 5% cost increase. Their problems are that they must be exposed to light for degradation to occur, that PD is inhibited when material is buried in a landfill or dumped in the ocean, and that PD additives used to impart photosensitivity may be toxic. However, they can be made with no loss of physical properties, or increase in film gauge, and they can generally be recycled. BD starch-based products are more expensive to produce with greater loading in the compounds and are limited to processing temperatures not higher than 230°C (445°F) before the starch is cooked or damaged. The wide range of particle size (3 to 5 μm for rice starch and 15 to 22 μm for potato starch) impairs film strength and clarity and puts a limit on down gauging. See **decomposition; landfill and degradation; photochemistry; photodegradable; photooxidation agent; starch degradable.**

biodegradable waste Products that can be disposed of by aerobic and nonaerobic degradation. Starch-based plastics are examples of a method used to dispose of paper and plastic packaging materials. Potatoes, wheat, and rice are used as the raw materials for the starch. This type of plastic undergoes aerobic and nonaerobic degradation and is targeted for products such as single-service food and medical products. At present their use is suitable for products that do not place high demands on physical and mechanical properties. The current emphasis on developing different types of biodegradable waste has overshadowed environmentalists' concern about whether it is more damaging to the environment and about the biological decomposition of plastics releasing their energy content without making it available for use. See **bacteria; biocide; biodegradable versus photodegradable; catalyst, enzyme; coating, microencapsulation; decomposition; degradable; deodorant additive; drug application; energy; environment; landfill and degradation; medical device packaging clarity; starch degradable.**

biodegrading microorganisms Genetically altered microorganisms that can biodegrade certain plastics, hazardous waste, oil, and so on. Because enzymes attack amorphous or noncrystalline regions, the resistance of susceptible plastics to microbial degradation is related to the degree of crystallinity of the plastics. They remain relatively immune to attack as long as their molecular weight remains high. In pollution control in the future, chemical companies will use tailor-made microbes instead of treatment plants. See **amorphous plastic; catalyst, enzyme; crystalline plastic; crystallinity and properties; engineering, generic; molecular weight.**

biological activity Plastics used in a biological environment: (1) plastics that are used as biomaterials, such as in organ replacement and bone surgery, (2) plastics that serve as matrices in devices that permit controlled release of an active substance over a long period of time, and (3) plastics that are soluble and that display biological activity. See **design biomedical product; drug-controlled delivery; medical applications; packaging biological substances.**

biological biocomputing Biological-inspired approaches to creating computer software. See **computer software.**

biological deposit A water-formed deposit of organisms or the product of their life processes.

biological indicator See **sterilization chemical indicator.**

biological packaging See **packaging biological substances.**

biomass The volume of living matter.

biomaterial A substance or combination of substances, synthetic or natural in origin, that can be used for any period of time, as a whole or as a part of a system that treats, augments, or replaces any tissue, organ, device, or function of the body. Certain plastics meet these criteria and are used in medical applications. See **design biomedical product; legal matter: biomaterial liability bill; medical market.**

biomedical plastic design See **design, biomedical product.**

biometric Technology that uses bodily characteristics like eyes, faces, hands, fingers, and voices to identify a person.

biorientation See **orientation, biaxial.**

bioplastic-biomedical See **biomaterial.**

biostabilizer See **waste biostabilizer.**

biotechnology See **design, biotechnology.**

bipolymer See **copolymer.**

birefringence The difference in the refractive indexes of two perpendicular directions in a given material such as a thermoplastic. When the refractive indexes measured along three mutually perpendicular axes are identical, they are classified as optically isotropic. When the thermoplastic is stretched, providing molecular orientation, and the refractive index parallel to the direction of stretching is altered so that it is no longer identical to what is perpendicular to this direction, the plastic displays birefringence. Techniques of birefringence range from the determination of structural defects in solid plastics to more basic investigations of molecular and morphological properties and are used in a wide range of applications.

Basically, birefringence is the contribution to the total birefringence of two-phase materials, due to deformation of the electric field associated with a propagating ray of light at anisotropically shaped phase boundaries. The effect may also occur with isotropic particles in an isotropic medium if they dispersed with a preferred orientation. The magnitude of the effect depends on the refractive index difference between the two phases and the shape of the dispersed particles. In thermoplastic systems the two phases may be crystalline and amorphous regions, plastic matrix and microvoids, or plastic and filler. See **amorphous plastic; coefficient of optical stress; compact disc; crystalline plastic; directional property, anisotropic;**

isotope; light index of refraction; magnetic-optical technology; orientation and optical property; photoelasticity; plastic, smart; polariscope; polarized light; stress, residual; test, nondestructive photoelastic stress-analysis; test, residual-stress.
biscuit See **preform.**
biscuit material See **material, biscuit.**
bismaleimide plastic See **polyimide plastic, bismaleimide.**
bisphenol-A A condensation product formed by the reaction of two (bi) molecules of phenol with acetone. This polyhydric phenol is a standard plastic intermediate along with epichlorohydrin in the production of epoxy plastics. See **epoxy plastic.**
biostabilizer, waste See **waste biostabilizer.**
bit See **computer bit.**
bitumen An asphaltlike natural or pyrogeneous hydrocarbon mixture and its nonmetallic derivatives, which may be solid or semisolid. Bitumens are found in asphalt, mineral waxes, petroleum, and lower grades of coal as products left after distillation. They are used in paints, coatings, sealants, roofings, hot melt adhesives, and road coatings.
bituminous plastic A compound containing bitumen with binders of phenolic plastics or Portland cement and mixtures of stearic pitch, asphalt, castor oil, benzyl, asbestos, sulfur, and iron oxide. Bituminous plastics are generally classed as organic (nonrefractory) or inorganic (refractory) types and are frequently processed by cold molding. See **molding, cold.**
black Any of several forms of finely divided carbon, either pure or admixed with oils, fats, or waxes. See **color standard; test, color; test, organoleptic taste.**
black and white Single color or monochrome; usually refers to artwork. See **artwork.**
blackbody See **radiation blackbody.**
black box A device whose method of working is ill-defined or not understood. See **coefficient of scatter; test, white-box and black-box.**
black, channel See **channel black.**
black dye See **dye toner.**
black lead See **graphite.**
black light See **light, black.**
black powder See **powder, black.**
black rouge See **iron oxide pigment.**
black speck See **speck, black.**
blank **1.** A part, such as a sheet, film, preform, parison, or casting, in some intermediate stage of fabrication such as forming, bending, blow molding, cupping, drawing, or hot pressing. See **forming; postforming; thermoforming; thermoforming, solid-phase pressure. 2.** An uncured thermoset material, such as an elastomer compound of suitable shape and volume, that fills a mold cavity in which it is cured or vulcanized. See **mold cavity.**
blanket **1.** Fiber or fabric plies that have been laid up in a complete reinforced plastic or laminate assembly and placed on or in the mold all at one time as in reinforced plastic-bag molding. See **laminate; reinforced plastic-bag molding** **2.** The type of bag in which the edges are sealed against a bag-molding mold.
blanking See **cutter, die.**
blast finish See **finish, blast.**
blast furnace See **furnace, blast.**
bleaching See **decolorizing agent.**
bleaching agent An oxidizing or reducing chemical such as sodium hypochloride, sulfur dioxide, sodium acid sulfite, or hydrogen peroxide. See **decolorizing agent.**
bleed **1.** To give up color when in contact with water or a solvent. See **migration. 2.** The undesired movement of certain materials in a plastic (plasticizer, lubricant, etc.) to the surface of the part or into adjacent material. Also called *migration*. See **colorant. 3.** An escape passage or vent (for example, at the parting line of a mold or the grooves in a blow mold) that permits cavity air or melt to escape. See **mold-cavity venting; reinforced plastic-bag molding; transfer molding. 4.** See **filament winding bleedout; screw, venting.**
bleeder cloth See **vent cloth; venting.**
bleed hole See **autoclave venting; reinforced-plastic venting cloth; venting.**
bleed, vent See **vent bleed.**
bleed, zero See **zero bleed.**
blend See **alloy/blend; polymer, reactive.**
blender A piece of equipment that is used for dispensing, metering, and mixing over the feed hopper or in other equipment operations such as compounding operations. Blenders can be motor-driven augers as well as air-driven valves to process materials such as flakes, powders, granular material, liquids, and pellets. See **blending; compounding; feed; material feeding and blending gravimetric; material feeding and blending volumetric; material handling; mill; mixer; mixer-blender, double-lane; mixer-blender with impeller; molding; plastic material.**
blender, conical dry A device consisting of two hollow cones that are joined at their bases by a short cylindrical section and are mounted on a horizontal shaft passing through the sides of the cylinder section. Material is charged and discharged at openings in the apexes of the cones. Cascading, rolling, and tumbling actions accomplish mixing as the cones rotate.
blender, dough A simple screw-type extruder that can prepare doughlike compounds. For example, its output for bulk-molding compounds that may be about 3 in. (8 cm) in diameter is cut into short lengths that are called *logs*. See **dough; mixer, paddle agitator; reinforced-plastic bulk-molding compound.**
blending Compounding or combining two or more material components. Blending is essentially the same as mixing but implies a higher degree of dispersion than simple mixing. The mechanical dry or wet mixing of ingredients ensures a uniform distribution of particles. When two or more plastics are mixed, several factors should be considered. One is whether their phases are ultimately miscible thermodynamically. In most cases where they are im-

miscible, which is predominantly the case with plastics, the minor components become the dispersed phases, and the major one becomes the so-called matrix or continuous phase. Therefore, another relevant factor is the ultimate desired phase morphology (spherical, lamella, cocontinuous, and so on). Other important factors include (1) the order of feeding (mixing protocol), the thermal glass transition temperature (T_g), melt temperature (T_m), and rheological (viscosity, melt elasticity) properties of each plastic; (2) whether the feed streams are solids, melts, or both; (3) the average stress levels; (4) the number of flow reorientations experienced by the melts; and (5) anticipated phase stability of the final morphology (resistance to coalescence) with respect to subsequent flow and heat histories downstream of the extruder mixing elements (pins, gears, kneading paddles, pelletizing operations, static mixers, and so on). See **alloy/blend; blender; bronzing; compatibilizer agent; compound, dry blend; compounding; interpenetrating network; material blending letdown ratio; material feeding and blending; migration; mixer, plastisol blending extender plastic; tumbling blender-mixer.**

blind search See **hypothesis.**

blister **1.** A cavity or sac that deforms the surface of a material. It is usually a raised area on the parts surface caused by the pressure of gases or air inside the part that surfaces during fabrication. See **defect; screw blister ring; sink mark. 2.** A thermoformed shape such as a building-ceiling window, aircraft canopy, or blister packaging. See **packaging, blister; thermoforming.**

block See **copolymer, block; curing agent, blocked; film blocking:** See **foamed polyurethane; expandable polystyrene block molding; polymer, block; polymerization, block.**

blockage An undesired cohesion between touching surfaces of materials, such as the cohesion that occurs with plastic film under just moderate pressure during storage or in use. Also called *blocking.* See **antiblocking agent; extruder melt blockage; film blocking; material blocking; sheet blocking.**

blood A complex liquid tissue of density 1.056 and pH 7.35 to 7.45. See **pH; medical applications; polyvinyl pyrroldone plastic.**

bloom **1.** The result of ingredients coming out of "solution" in the fabricated plastic product and migrating to its surface. See **bleed; migration. 2.** An increase in diameter of the blow-molding parison as it exits the extruder die. See **blow-molding extruder parison. 3.** A surface film resulting from attack by the atmosphere or from the deposition of smoke or other substances such as vapors. See **contamination; lubricant bloom; phosphorous-base flame retardant; smog.**

blow-head The part of a forming machine, such as blow molding and thermoforming, that introduces air under pressure to blow any hollow product. See **blow molding, extruder blow-action; thermoforming.**

blowhole **1.** A hole produced in a casting or other solid plastic fabricated product where unwanted gas (such as air) is trapped during solidification. **2.** A pinhole, blowout or fisheye, that is evident on the wall surfaces of a blown container. These defects may be caused by conditions such as contamination by water and other substances, improper drying plastics, improper blowing, and melt sticking to the core rod.

blowing Using a gas in expanding plastic melt by different processes such as foaming, thermoforming, blow molding, and expandable plastic.

blowing agent A material used to produce gas by chemical action, thermal action, or both in the fabrication of hollow or cellular products. See **environmentally friendly additive; expandable polystyrene; foam and blowing agent.**

blowing film See **extruder blown film.**

blowing glass The shaping of hot glass by air pressure. Over a century ago, hot-plastic blow molding evolved based on ancient glass-blowing techniques. See **blow molding; blow-molding glass, press-and-blow process for.**

blow/injection molding with rotation See **blow molding, injection-with-rotation.**

blown film See **extruder blown film; film.**

blow molding (BM) Blow molding can be divided into three major processing categories: (1) extruded BM has continuous or intermittent melt (called a *parison*) from an extruder and principally uses an unsupported parison, (2) injection BM has noncontinuous melt (called a *preform*) from an extruder and principally uses a preform supported by a metal core pin, and (3) stretched/oriented EBM and IBM obtains bioriented products providing significantly improved performance-to-cost advantages. These BM processes offer different advantages in producing different types of products based on the plastics to be used, performance requirements, production quantity, and costs. See **blow molding innovation; extruder; processing fundamental.**

Basically the BM lines have an extruder with a die to form the parison or with an injection mold to form the preform. The hot parison or preform is located in a mold. Air pressure through a pin-type device expands the parison or preform to fit snugly inside the mold cavity. Blow-molded products are cooled via the water-cooling systems within mold channels. After cooling, the parts are removed from their respective molds. See **blow molding mold; Coca-Cola bottle; bottle, beer; foundry shell molding.**

blow molding accumulator See **accumulator.**

blow molding adapter system See **adapter system.**

blow molding air pressure Clean compressed air that is supplied to "blow" the hot melt located within the blow mold. Other gases can be used, such as carbon dioxide, to speed up cooling of the blown melt in the mold. The gas usually requires at least a pressure of 30 to 90 psi (0.21 to

0.62 MPa) for extruded blow molding and 80 to 145 psi (0.55 to 1 MPa) for injection blow molding. Some of the melts may go as high as 300 psi (2.1 MPa). However, stretch EBM or IBM often requires a pressure up to 580 psi (4 MPa). The lower pressures generally create lower internal stresses in the solidified plastics and a more proportional stress distribution; the higher pressures provide faster molding cycles and ensure conformity to complex shapes. With lower pressure or lower melt stresses comes improved resistance to all types of strain (tensile, impact, bending, environment, and so on). See **blow molding, extruder blow-action; blow molding, injection blow-action; carbon dioxide.**

blow molding air pressure, chilled Production can increase usually by at least 20 to 40% by using aggressive, turbulent chilled air at about −35°C (−30°F) that is allowed to escape. This action provides several changes of air through the blow pin during a single blowing cycle.

blow molding barrel See **barrel; plasticator.**

blow molding barrel downsizing and upsizing See **barrel downsizing and upsizing.**

blow molding blow cavity The final outside blown plastic part shape that conforms to the mold cavity shape. See **blow molding mold.**

blow molding blow-head See **blow-head.**

blow molding blow rate The speed or rate that the blown air or medium enters or the time required to expand the parison or preform during the blow-molding cycle.

blow molding blow-up ratio See **blow-up ratio.**

blow molding bottle A bottle that is predominantly fabricated using the extrusion and injection molding process with or without stretching/orientation. See **barrier; blow molding; bottle; coating, oxygen-barrier removable; Coca-Cola bottle; design, collapsible-bottle.**

blow molding clamping A two-part clamping system that supports and operates the opening and closing of the mold halves. Clamp pressure is applied to ensure that a closed mold remains closed when air pressure is applied to the parison or preform. See **clamping; clamping platen; mold halve.**

blow molding clamping, shuttle See **clamping, platen, shuttle.**

blow molding cleaning See **cleaning.**

blow molding coextrusion or coinjection The use of blow-molding multilayer plastics is a technology that provides the advantages of using differing materials, including plastic foams that are systematically combined to meet cost to performance requirements. See **foam; blow molding, extruder-sequential; coextrusion; coinjection molding; extruder, foam.**

blow molding coextrusion foam Coextruded foam blow molding reduces part density by 5 to 50%, saving material and adding strength. The process can make parts with two or three layers of foam and skin, using two or three extruders. Temperature and the amount of blowing agent control thickness of the skin and foam. Foamed BM takes much lower air pressure than conventional BM (~0.5 to 1 bar versus 5 to 10 bar). More pressure could collapse the foam. However, the same surface quality is generally not obtained. With slow and controllable foaming agents that temper the bubbly action of the dropping extruded parison or the movement of the injection preform, products can be BM particularly multilayer construction. See **blow-molding coextrusion or coinjection; blow molding, extruder-sequential; coextrusion; coextrusion foam core; coinjection molding; foam.**

blow molding cold parison and preform In a two-stage system, the extruded parison (or tube) or preform is processed and cooled, stored, and when customer orders arrive, used in a second-stage blow-molding machine that reheats them and makes blow-molded products.

blow-molding communication protocol See **communication protocol.**

blow-molding complex parts See **blow-molding, extruder three-dimensional.**

blow molding, compression-stretched (CSBM) A process during which (1) circular blanks are cut from an extruder sheet, (2) the blanks are compression molded into the desired preliminary shape, (3) during the compression action, the blank can be simultaneously stretched, (4) stretching can take place after compression molding, and (5) any trimming that may be required. Compression-stretch blow-molding patents include (1) those held by the Valyi Institute for Plastic Forming (VIPF) located at the University of Massachusetts at Lowell, (2) Dynaplast S.A.'s Co-Blow system, (3) American Can's OMNI container, (4) Petainer's cold forming process, (5) Dow Chemical's solid phase forming, and (6) Dow Chemical's coforming (COFO). See **blow molding, stretched operation specialty; forming, scrapless.**

blow molding, computer-integrated See **blow molding, extruder-parison programmed-control; computer-integrated manufacturing.**

blow molding, container leakage in See **container leakage.**

blow molding, dip and displacement A process that requires two sets of one or more dipping mandrels, equipped with a neck forming tool, operating in tandem. One set is dipped into a feed port (pot) containing plastic melt that was injected (by an injection molding machine) into the shaped preform cavities. The mandrel is coated with the melt. At this stage the neck finish can be formed under low pressure. Next, the coated mandrels are lifted from the melt pot and shuttled sideways to descend into a cavity mold for blowing. Simultaneously as this coated mandrel leaves the pot area, an uncoated mandrel is positioned into the pot that has been refilled with melt. In turn as this coated mandrel is being lifted, the blown bottle has cooled and is also being lifted to be released. The dipping and blowing mandrels can be positioned on the same support plate so that the simultaneous actions occur following repeat cycles. See **blow molding, stretched operation specialty; casting, dip.**

blow molding downtime See **processing-line downtime; processing-line uptime.**

blow-molding drawdown See **blow molding, extruder parison draw-down.**

blow molding energy saver See **electric motor, adjustable-speed-drive; energy loss, machine; extruder drive-energy consumption.**

blow molding exhaust time The length of time required to relieve the blown air pressure in the molded part before opening the mold.

blow molding, extruder See **extruder.**

blow molding, extruder-accumulator A device for storing plastic melt in the intermittent operation. Melt moves from the extruder to the accumulator and in turn moves by ram action through the dies to produce parisons. The accumulator is designed so that literally all the melt leaves it so that damaging heat history (residence time) of the melt will not occur; this action is usually referred to as *first-in to first-out*. As the parison is being formed, the accumulator is reloaded with melt, and this cycle repeats automatically. See **accumulator; residence time.**

The advantages of continuous BM usually include excellent parison programming, excellent die tooling profile, faster color change, and faster cycle times. With the accumulator, advantages generally include excellent processing of low-melt-strength plastics, blowing of larger parts, creation of larger-diameter parison drops, and creation of parts with long pinchoff, where considerable clamp tonnage is needed and available since it is required for the larger parts. The larger parts use the accumulator. However there is an overlapping area where a given part can use either system.

blow molding, extruder back pressure See **back pressure.**

blow molding, extruder blow-action Techniques that are used in blowing air into the parison. The usual is a tube through the die head or at the opposite side of the die head where the bottom pinch-off is located. A hollow needle can be used with a sharp end, such as a hypodermic needle, that pierces the parison usually at the mold parting line. It can be withdrawn prior to solidification of the melt so that no hole remains in the blown product. With a careful setup, relatively no pinhole mark will be visible. This technique has been used for over a century (for example, in fabricating Christmas decorations). See **blow-molding air pressure, chilled; blow molding, injection blow-action.**

blow molding, extruder blow, fill, and seal In an in-line system, after the parts are blown, they can be filled and sealed before the mold opens. The other methods have the filling and sealing downstream or in another line after parts are blown. See **thermoforming, form, fill, and seal; seal.**

extruder blow pin See **blow molding, extruder blow-action.**

blow molding, extruder blow-up ratio See **blow-up ratio.**

blow molding, extruder bottle handle See **blow-molding handle.**

blow molding, extruder bottle-volume adjustment A movable plug that is set to control the contents of a bottle. The mold of the bottle's sidewall can have a depression plug, small and usually circular, that is usually adjusted inwardly based on the performance of the blown bottle. It is important for sales purposes that, for example, a milk container looks full and contains a specific quantity. The level of the milk can differ among bottles and appear that the contents are not equal due to shrinkage differentials that can occur after the bottle is blown or to changes in the material properties.

blow molding, extruder bottom-blow The blowing action from the bottom of the part being blown.

blow molding, extruder coextrusion See **blow-molding coextrusion or coinjection.**

blow molding, extruder cold parison See **blow-molding cold parison and preform.**

blow molding, extruder collapsible bottle See **design, collapsible-bottle.**

blow molding, extruder (continuous) In extruder blow-molding, the melted plastic from the extruder through a die head is continuously extruded as a parison (also called a *tube*) vertically down into the atmospheric air. It is located between the two halves of an open mold. The melt flowing through the die can form different cross-sections with or without changes in the parison's wall thickness as it exits the die. When the parison has reached its required length, long enough to cover the height of the mold cavity, the open mold closes around the hot parison. A blow pin either is located or is inserted through the parison melt, permitting air to enter. Different molds and blow pins (with different locations around the mold cavity) are designed to meet different requirements.

Unlike IBM, when the mold closes flash exists normally only at the top and bottom of the mold cavity. This excess plastic is formed when the parison is pinched by the mold's "pinch-off," usually at the top and the bottom of the cavity. As an example with a bottle when the mold closes, the top has its threaded opening with flash around it, and simultaneously the bottom of the parison's pinch-off is sealed to contain the blown air producing a "hanging" flash below the pinch-off. Molds can be designed where automatically all the flash is removed within the mold, or the line will have a secondary operation to remove the flash after the cooled part leaves the mold.

blow molding, extruder (continuous-die) In the extruder blow-molding machine, a die can have one or more parisons exiting. This multiparison approach uses a mold with the number of cavities equal to the number of parisons. This multiple approach increases production, provided the extruder output capacity is adequate. With this continuous EBM process the closed mold with the parisons can be moved downward from the continuing dropping parisons. This method has the parisons continuously extruded. When the parisons reach the proper length, the open mold cavities located around the parisons quickly close, pinching the parisons. The closed mold quickly returns to a position away from the parison drop. Automatically blow pins are located within the parisons. The mold could be below the parisons or to the side so that the parisons continue to extrude with no interruption. After the part is blown and cooled, the molds open, the parts are removed, the mold moves back to the parisons, and the process repeats. Having the parison continually move provides for better reproducibility of the melt. See **die; melt flow; mold.**

blow molding, extruder (continuous-operation) In addition to the up-and-down or side motion methods, other modes of operations increase production. Three other popular modes of operation are the rotary wheel with its two modes (carousal system or ferris wheel) and a shuttle mode. The rotary-wheel method uses at least 2 to 20 clamping stations with the molds. These stations are mounted to a vertical or horizontal wheel. In one approach, the die with its parison moves around in the path of the molds. A mold is opened while the parison is moving through it. The mold closes, pinching the parison, and starts its cycle of blow, cool, and eject by opening the mold. In the meantime, the next mold is opened, and the parison is pinched and so on. This system is timed so that when the parison drop returns to the first mold, which is an open mold with part removed, the rotary system continues and repeats. The other rotary approach is having the molds move with the parison remaining in a fixed location.

The third mode is the shuttle method, where usually two or more sets of molds are used. Each set of molds can have at least two or more molds. Their blowing stations are around the periphery of the extruder die head and parisons. One set of molds in the open position is located under the die. With the proper length of the parisons (a parison for each mold), the open molds underneath close. After the molds are closed, parisons are cut, usually with an electrically charged hot wire, and quickly shuttled to a blow station, where blow pins are inserted into the parison openings. Blow-molding parts solidify and are released from the molds when they open. In the meantime, the parisons continue to be extruded as another set of open molds is positioned around these parisons. Thus, the molds alternately shuttle producing molded parts.

Another approach to increase production is to use one parison extra long to cover two or more cavities located vertically in the mold. In fact, one parison can extend the multiparison with two or more vertical cavities. All that is required is a machine with the capacity to handle the output from the extruder to the clamping capability. See **blow molding, extruder horizontal rotary-wheel; blow molding, extruder vertical rotary-wheel; clamping platen, rotary; clamping platen, shuttle; mold cavity.**

blow-molding extruder core An extruder die part that controls the inside dimensions of the parison. See **core; die.**

blow molding, extruder curtaining Vertical draping or folding that is caused by the parison's vertical-free drop, which swells, grows in diameter, and reduces thickness as it is extruded. Because of the gravitational forces, the parison tends to hang directly below the die opening. As its circumference swells and grows, it tends to fold and wrinkle beneath the die; however, it can be controlled to provide a desirable blown part.

blow molding, extruder cushion See **cushion.**

blow molding, extruder, cut-off Blow-mold pinch-off areas produce weld lines. These lines (top and bottom) are where the mold pinch-off areas can be cut through the parison when it closed on the parison for blowing. See **blow molding, extruder, pinch-off; weld line.**

blow molding, extruder, cycle time See **cycle.**

blow molding, extruder, die A die used with extruder blow molding. It takes the melt from the (usual) horizontal extruder and changes its direction to have it exit the die vertically downward (also horizontal in special machines such as when using a rotary table with two or more molds). The die can be designed to permit a change in the thickness of the exiting hot melt. Different die designs are used to meet different processing requirements. With accumulator systems to ensure that the least heat history or residence time is developed during processing, the design of the accumulator ensures the first melt into the accumulator is the first to go out when its "ram" literally empties the accumulator chamber. See **blow molding, extruder (continuous operation); die; die manifold; residence time.**

blow molding, extruder, die-head manifold See **die manifold.**

blow molding, extruder, die ring, static and dynamic See **die ring, static and dynamic.**

blow molding, extruder, die shaping Usually the die shape of the extrudate is circular. Depending on the final product, the die can be designed to provide shapes that are elliptical to square. A die opening for a square shape can be designed to extrude a nonuniform or uniform wall thickness including the corners. See **die, profile special.**

blow molding, extruder, die-swell ratio The ratio of the outer parison diameter, or parison thickness, to the outer diameter of the die, or die gap, respectively. The type plastic, head construction, land length, extrudate output speed, and extrudate temperature influence die swell ratio. See **design, basics-of-flow die.**

blow molding, extruder, double-wall A double-walled blown part, such as a lid container.

blow molding, extruder, drape-process It identifies multidimensional extruder blow molding where flash is minimized.

blow molding, extruder, exhaust-time The length of time required to relieve the blowing air pressure in the molded part before opening the mold.

blow molding, extruder, feeder See **feeder.**
blow molding, extruder, flat-surface With certain products, flat surfaces can cause oil canning. The flat surfaces that are supposed to be rigid or firm will bend or flex. Techniques to eliminate the problem include crowning, arching, corrugations, ribbing, and foam filling. See **oil canning.**
blow molding, extruder, foam See **blow molding coextrusion foam; blow molding coextrusion or coinjection; foam.**
blow molding, extruder, fuel-tank See **gasoline tank permeability.**
blow molding, extruder, gear-pump See **gear pump.**
blow molding, extruder, horizontal rotary-wheel A system that uses the principle of a continuous extruder blow molding parison that is like a continuous tube that moves from the die into an open mold and continues to form parts where the flash between parts keep the wheel operating continuously. See **blow molding, extruder (continuous operation); blow molding, extruder vertical rotary-wheel.**
blow molding, extruder (intermittent) With an accumulator located above the die, the flow of the parison through the die is cyclic, permitting intermittent or discontinuous extruder blow molding. These systems can fall into two modes where an accumulator or reciprocating screw is used. The accumulator head is used to mold small to particularly large parts. Accumulator heads attached to the exit end of the extruders are designed to collect and eject a measured amount of plastics. See **blow molding, extruder-accumulator.**

The other mode is the reciprocating screw or a noncontinuous extruder. It is actually a single-stage injection molding machine (IMM). Plastic is conveyed and melted by the screw turning. As the melt accumulates in the front of the screw within the barrel and has the required quantity (shot size), the screw stops turning and when required pushes forward (ram), forcing the melt through a die to form a parison. Basically all that is needed is an IMM having the required shot size with a die to form the parison followed with a blow-molding mold rather than just the usual IM mold. See **injection molding.**

The advantages of intermittent BM are usually better control of melt strength and swell, easier handling of large blown parts, and use of fewer plant utilities. Continuous advantages include better thermal stability and melt control and use of less plant space. Both methods are used in a one-step blow-molding method. With the two-stage method, basically a conventional IMM is used to mold preforms, short or long tubes, that are solidified, stored, and blown in a second machine that only does the blowing.
blow molding, extruder-mold The two-part mold has its parting line in the longitudinal direction of the blown part or in the direction of the dropping parison. With commodity plastics, a sandblasted mold-cavity surface can usually be used to aid in air venting (between the parison and cavity wall) and also to provide a smooth surface on the blown part; a characteristic of most melts generally prevents penetration of the "rough" surface. With engineering plastics, the surface of the cavity is generally reproduced precisely, so sandblasting is not used. When venting is required, vents are usually located on the mold's parting line. For certain molds, holes or slots are located where needed. They are kept as small as possible so the blown melt does not have an impression of the opening. Their sizes can start with a range of 0.002 to 0.004 in. (0.05 to 0.10 mm). If necessary, they are made larger. Different plastics behave differently so actual sizes are based on experience or trial and error. See **blow-molding mold; bottle, cryogenically cooled filing; commodity plastic; engineering plastic; mold; mold-parting line; venting.**
blow molding, extruder-mold bluing See **mold bluing.**
blow molding, extruder-mold cooling See **mold cooling; mold cooling, flood.**
blow molding, extruder-mold deflashing The in-mold deflashing process separates a blow-molded part from its flash as the mold opens eliminating secondary deflashing operations. The technique can incorporate moving plates and bars that, simply stated, hold the flash to one mold half with a plate while a bar pushes the flash away from the pinch-off as the mold opens, during which time the sealing action has occurred but the flash section remains sufficiently warm for the proper separation.
blow molding, extruder-mold multiple-action Typical parts are the molding of a complete container with what will become its overlapping lid, such as a trash can or threaded lids to bottles. After blow molding the part is cut so that the lid and container will match properly.
blow molding, extruder-mold multiple, siamese A colloquial term applied to the technique of blow molding two or more products from a single parison in a multiple-cavity mold.
blow molding, extruder-mold pinch-off A critical part of a mold where the parison is squeezed and welded together. It requires good thermal conductivity for rapid cooling and good toughness to ensure long production runs. The pinch-off must have structural soundness to withstand the plastic pressure and repeated closing cycle of the mold. It must usually push a small amount of plastic into the interior of the part to slightly thicken and reinforce the weld. If this pocket depth is too shallow, the flash will be squeezed with too much pressure, putting undue strain on the mold, mold pinch-off areas, and machine clamp-press sections. If the pocket is too deep, the flash will not contact the mold surface for proper cooling. Between molding and automatic trimming, heat from the uncooled flash will migrate into the cool pinch-off and cause it to heat up, creating problems like sticking to the trimmer. During trimming it can stretch instead of breaking free and clean. Different designs are used with different plastics welding characteristics. The typical designs have double-angle (from 15 to 45°) opening of the pinch land

contact on its exit side. Its land length, prior to the angles, can range from 0.010 to 0.030 in. (0.025 to 0.076 cm). Also called *cut-off.*

blow molding, extruder, multiple-cavity If machine capacity is available, in-line with the parison drop, the mold can have two or more cavities to blow mold parts in-line with the parison.

blow molding, extruder, parison The hollow tube of melt exiting the extruder die, which in turn is pinched at both ends and inflated with air to the contour of the closed mold cavity. See **mold cavity; striation.**

blow molding, extruder, parison bloom See **bloom.**

blow molding, extruder, parison draw-down The decrease in parison diameter and wall thickness due to gravity and the weight of the parison as it extends downward. See **draw-down ratio.**

blow molding, extruder, parison preblow If the parison tends to collapse and bond to itself, during the parison drop, low pressure air is initially introduced during the drop to eliminate the problem.

blow molding, extruder, parison clamping preclose See **clamping preclose.**

blow molding, extruder, parison curling See **curling.**

blow molding, extruder, parison programmed-control For extruder blow molding, the parison thickness control is important to reduce processing time, maximize part design, and reduce the amount of plastics consumed. The thickness profile in its length direction is programmed to equalize the wall thickness of the blown product when blown. Their control and monitoring functions range from extremely simple ones to complete microprocessor systems. Some machines use electric relays that permit a certain degree of control. However, to produce good-quality parts with the least plastic resulting in lower product costs, the more sophisticated electronic types are required.

The most common method is an orifice modulation. The die is fitted with a position device that allows positioning of the inside taper die diameter during the parison drop. The outside- and inside-diameter relationship of the tapered die orifice opening is varied in a programmed, repeatable manner to increase or decrease the parison wall thickness. The parison, especially a large one as it gets longer, the wall thickness will vary as the weight of the plastic increase and it sags. Parison control can include melt-pressure control in the die, either by regulating the extruder's back pressure or possibly by pressure variations via the ram action when an accumulator is used. In addition to this longitudinal control, there are also circumferential distribution controllers such as going from circular to elliptical parison shape. See **back pressure; computer-integrated manufacturing; control actuator; die head, programmed; die ring, static or dynamic; microprocessor control; process control.**

blow molding, extruder, parison sag The extension, usually near the die face, of the parison during extrusion by gravitational forces. The longer the parison, the more the sag develops. This necking down of the parison can cause fabricated part problems. The problem can be controlled with higher-melt-strength plastic or by controlling the thickness of the melt as it leaves the die. See **blow-molding fold area.**

blow molding, extruder, parison swell See **design, basics-of-flow die.**

blow molding, extruder, part thickness See **blow molding, extruder parison programmed-control.**

blow molding, extruder, pinch-off The line where the two halves of a blow mold come together. Also called *flash groove* or *cut-off.* See **blow molding, extruder cutoff.**

blow molding, extruder, pinch-off relief edge The angle in the mold of the cutaway portion of the pinch-off blade measured from a line parallel to the pinch-off land.

blow molding, extruder, pinch-off tail The bottom (outside of the blown part) of the parison that is pinched when the mold closes.

blow molding, extruder, plastic melt index (MI) Melt index and other melt-flow characteristics directly influence blow-molding capability. For example, large parts, such as plastic fuel tanks, drums, and trash cans, are BM from low MI, high-molecular-weight polyethylenes providing a more stable parison, tougher products with up to 5 to 10% reduction in weight compared to the higher MI plastics. See **test, melt-index.**

blow molding, extruder, plastic scrap Representative of the flash that develops during blow molding. See **scrap.**

blow molding, extruder, platform blowing A technique for blow molding large parts to prevent excessive sagging of the heavy parison. The machine has a table that, after rising to meet the parison at the die, descends with the parison but at a slightly slower rate than the parison.

blow molding, extruder, pock mark An irregular indentation on the surface of a blown product that is caused by insufficient contact of the blown parison with the mold surface. Pock marks are usually caused by low blow pressure, air or gas entrapment, or moisture condensation on the mold-cavity surface.

blow molding, extruder, preblow The injection of a medium, such as the usual air, into a closed parison before the mold closes to aid in developing the blown shape desired.

blow molding, extruder, prepinch parison Closing off an open end of the parison before the mold pinches it together. Often used in conjunction with the preblow action.

blow molding, extruder, reinforced plastic A development by Krupp Kautex that uses two methods of providing increased structural properties through the use of long glass fiber reinforcement with polypropylene. The 15wt% content use 7 mm long fibers. One approach extrudes unreinforced melt into a low-shear Z-blade or sigma-blade batch kneader. Dry chopped glass fibers are blended into the melt under vacuum, and a discharge screw in the mixer's bottom feeds the compound to the blow molders accumulator head. Another approach is to use commercially available glass fiber/PP compounded pellets made by the pultrusion process. Pellets are plasticized using a special screw that melts by heat conduction rather than by shear to minimize fiber damage. Parison is blown initially at very low air pressure; after complete expansion, full pressure is used. See **mixer, sigma blade; reinforced plastic; reinforced-plastic pultrusion.**

blow molding, extruder, sequential. Material is fed to the parison and is changed as it emerges. For example, a rigid compound might be formed with intermittent elastomeric sections to form a pipe or duct embodying flexible bellows that enable it to twist and turn. Other parts might be made with properties changing or alternating throughout the longitudinal axis of the parison so that one side is hard and the mating other side is soft; an example is an armrest on an auto chair. Basically, a coextruder control system is used to direct the different melts as required or at the appropriate time periods. See **blow molding, coextrusion foam; coextrusion; coinjection molding.**

blow molding, extruder, single-stage See **blow-molding extruder stage.**

blow molding, extruder, specification See **extruder specification.**

blow-molding, extruder, stage There are basically a single-stage system and a two-stage system. With the single-stage, one machine performs all that is required going from the plastic material to the blown product. The two-stage method uses two machines. One extrudes tubes (short or long tubes where the long tubes can be cut to the desired lengths) and has them solidified, stored, and blown in a second machine that does the blowing by reheating the preforms. See **blow molding, extruder (intermittent); blow molding, injection preform one- or two-step.**

blow molding, extruder, stretched See **blow molding, stretched.**

blow molding, extruder-thermoformed See **blow molding, stretched operation specialty.**

blow molding, extruder, three-dimensional In conventional blow molding the parison enters the mold rather in a straight tube. In three-dimensional BM the parison is laid or oriented in the mold prior to closing. It is manipulated in the tool cavity providing complex geometric parts that can have uniform or nonuniform wall thicknesses, corrugated and noncorrugated sections, and so on. Different techniques are used for placing the parison into position, such as (1) articulating the extruder nozzle, (2) articulating the mold platen, and (3) robotically orienting the parison before the mold closes. Thus, different- shaped BM parts are fabricated. Sequential BM integrates hard and soft regions of plastics on a single tubular structure (parison). Also called *nonaxisymmetric blow molding*. See **robot.**

blow molding, extruder, top blow The usual type of blow-molding machine that forms hollow articles by injecting the blowing action into the parison at the top of the mold.

blow molding, extruder, two-stage See **blow molding extruder stage.**

blow molding, extruder, troubleshooting in See **troubleshooting.**

blow molding, extruder, two-up molding See **blow molding, extruder multiple-cavity.**

blow molding, extruder versus injection The advantages of extruder blow molding versus injection blow molding include lower tooling costs and incorporation of blown handle-ware. Disadvantages could be controlling parison swell, producing scrap, limited wall thickness control, and plastic distribution. If desired, solid handles can be molded during the blow-molding process. Trimming can be accomplished in the mold for certain designed molds. Secondary trimming operations are included in the production lines.

With IBM, the main advantages are that no flash or scrap occurs during processing, it gives the best of all thicknesses and plastic distribution control, critical bottle neck finishes are easily molded to a high accuracy, and it provides the best surface finish. Disadvantages include it has high tooling costs, applies only to solid handle-ware, and it is restricted or usually limited to very small products (however large and complex shaped parts are fabricated once the market developed). Similar comparisons exist with biaxial orienting EBM or IBM. With respect to coextrusion, the two methods also have similar advantages and disadvantages but mainly more advantages for both. See **blow molding, injection-operation.**

blow molding, extruder, vertical rotary wheel Similar to the horizontal wheel except the wheel is in the vertical position. See **blow molding, extruder (continuous operation); blow molding, extruder, horizontal rotary-wheel.**

blow molding feeder See **feeder.**

blow molding foamed plastic See **blow molding coextrusion foam.**

blow molding fold area Areas of excess plastic in the finished blow-molding product can have an unwanted fold. The plastic parison or preform sagging or more likely blowing out unevenly during the blowing process may form it. See **blow molding, extruder, parison sag.**

blow molding glass, press-and-blow process for A process usually associated with blown-glass manufacture in which the glass parison is pressed, and in another step, the heated parison is blown to form the final shape. See **blowing glass; glass.**

blow molding handle Extrusion blow molding can include an integral blown handle. With injection BM a solid handle can be included during the blowing action. One approach is to include the solid handle as an integral part in the preform next to the neck and the other end of the handle either away from the blown part (attached as part of the neck section) or not attached to the blown section. With stretched blow molding, solid handles can be included next to the neck.

blow molding heat-transfer mechanism See **heat-transfer mechanism.**

blow molding hinge See **design hinge, integral.**

blow molding, injection (IBM) Injection blow molding has basically three major stages: (1) The first stage injects hot melt through the nozzle of an injection-molding machine into a mold with one or more cavities and core pins to produce the preforms. There is usually more than one cavity. An exact amount of plastic enters each cavity. These molds are designed as in regular IMM to meet the required BM melt temperatures and pressures. After injection of the melt into the mold cavities the two-part mold opens. The core pins carry the hot plastic preforms to the second stage of the operation, where a two-part mold has the desired mold cavities for blow molding. Upon the mold closing in this second stage, air is introduced via the core pins, producing the desired blown products.

(2) Controlled chill water (usually 40 to 50°F [4 to 10°C]) circulates through predesigned mold channels around the mold cavities and solidifies the blown parts. This two-part mold that did the blowing opens when the parts solidify. (3) In turn, the core pins carry the blown parts to the third stage. In that stage the parts are ejected. Ejection can be done by using stripper plates, air blowing, combination of stripper plate and air, robots, and so on. See **blow molding, extruder-mold; injection molding; mold.**

blow molding, injection, back pressure See **back pressure.**

blow molding, injection, blow-action Air, for the blowing action, is usually from the end or part of the core pin that forms the parison. See **blow-molding air pressure, chilled; blow molding, extruder blow-action.**

blow molding, injection, bottle handle See **blow-molding handle.**

blow molding, injection, Coca-Cola bottle See **Coca-Cola bottle.**

blow molding, injection/coinjection See **coinjection molding; blow-molding coextrusion or coinjection.**

blow molding, injection, cold preform See **blow molding cold parison and preform.**

blow molding, injection, cycle See **cycle.**

blow molding, injection, insert In injection blow molding, to reinforce the neck, extra plastic can be located in that section making a thicker neck or a plastic IM insert can be placed in the blow-mold cavity neck section prior to locating the preform in the cavity.

blow molding, injection, mold See **blow molding, extruder-mold; mold.**

blow molding, injection, mold bluing See **mold bluing.**

blow molding, injection, mold filling See **injection molding melt flow; mold-filling monitoring.**

blow molding, injection, operation Injection blow molding can have the usual three stations (stages) of the preform melt injection, blow action, and ejection of the blown products from the mold pins. Some machines have more than the usual three stations. A station can be located between the preform stage and the blowing stage to provide extra heat-conditioning time for the preforms. Between the blow and ejection, a station can be used to apply decals, decoration, test dimensions, and so on. After ejection, a station can be used to add an insert for decoration, reinforcement, and so on. Also available are several different methods of IBM, each with different means of transporting the core rods from one station to another. These methods include shuttle, multiparison rotary, and so on. The information on blowing parisons, cooling, clamping, and shrinkage that is used for extrusion blow molding is similar for IBM.

When compared to EBM, this IM procedure permits the use of plastics that are unsuitable for EBM (unless modified). Specifically it is those with no controllable melt strength such as the conventional polyethylene terephalate, which is predominantly used in large quantities using the stretch IBM method for carbonated beverage bottle (liter and other sizes). These injection blow-molded products have precise dimensions. This action occurs since the initial preforming cavities are designed to have the exact dimensions required after blowing the plastic melt as well as accounting for any shrinkage that may occur. Another advantage is that no flash or scrap exists. Neck finishes, internally and externally, can be molded with an accuracy of at least ±4 mil (0.10 mm). It also offers precise weight control in the finished product accurate to at least ±0.1 g. See **blow-molding, extruder versus injection.**

blow molding, injection, preform A tube, similar to a laboratory test tube but much thicker and heavier. The tube is hollow and matches the shape of the rod. All the dimensions of a preform are precise so that when it is blown, a precise product is formed.

blow molding, injection, preform one- or two-step The preform is used to fabricate the injection blow-molded product either in a one-step or two-step operation. The one-step goes from the injection molding to the finished blown product. The two-step first produces the preformed, and in turn the cool preform is later put into another machine where it is reheated and blown to produce the product. An example of production output for the one-step polyethylene terephalate plastic machine is at least up to 4,000 bottles per hour. See **blow-molding extruder stage.**

blow molding, injection, stretched See **blow molding, stretched.**

blow molding, injection versus extruder See **blow molding extruder versus injection; blow molding, injection-operation.**

blow molding, injection-with-rotation A blow-molding process called *molding with rotation* (MWR) that combines injection molding and injection blow molding with melt orientation (Dow Chemical patent). The equipment used is what is commercially available for IM except the mold is modified. The male or female part of the mold rotates; usually the male core rod is rotated. This process provides a practical approach by which multiaxial orientation can ensure maximum properties in the molded part that can be a bottle or other shape having a polar axis of symmetry and reasonably uniform wall thickness. Orientation of the melt in micron-thick multiple layers occurs during injection of the melt as it rotates at a controlled speed, pressure, temperature cycle period. After this action is completed, the oriented melt around its pin is quickly transferred to a mold for its required blowing stage. Also called *injection spin molding* or *injection stretched molding*. See **Coor's beer bottle; orientation.**

blow molding innovation Ideas from tapered to collapsible corrugated are used to fabricate products that produce blow-molded type bottles and containers. They include other basic processes such as casting, compression molding, and stamping. See **blow molding, compression-stretched; blow molding, stretched operation specialty; computerized knowledge-based engineering; design, innovative; forming, scrapless.**

blow molding machine alignment See **machine alignment.**

blow-molding machine barrel See **barrel, extruder and injection molding.**

blow molding machine barrel and feed unit See **barrel and feed unit.**

blow molding machine-barrel downsizing and upsizing See **barrel downsizing and upsizing.**

blow molding machine clamping See **clamping.**

blow-molding machine control See **accuracy; computer-integrated manufacture; controlled motion; design, motion-control, mechanical and electronic effects; drive-system control; electric motor; injection-molding machine electrical operation; injection-molding machine hydraulic operation; process control; repeatability; servo-control-drive reliability.**

blow molding machine daylight See **clamping, daylight-opening.**

blow molding machine die See **die.**

blow molding machine energy See **electric motor, adjustable-speed-drive; energy input, machine; energy loss, machine.**

blow molding machine fabricator process simulator See **process simulator.**

blow molding machine gear pump See **gear pump.**

blow molding machine maintenance See **maintenance.**

blow molding machine mold See **blow molding mold.**

blow molding machine operation See **fabricating startup and shutdown.**

blow molding machine platen See **clamping platen; platen.**

blow molding machine purging See **purging.**

blow molding machine safety See **safety and machines; safety machine lockout.**

blow molding machine screw See **screw.**

blow molding machine screw L/D ratio See **screw length-to-diameter ratio.**

blow molding machine screw wear See **screw wear.**

blow molding machine static mixer See **static mixer.**

blow molding machine vented See **screw, venting.**

blow molding machine warranty See **legal matter warranty.**

blow molding mandrel See **mandrel.**

blow molding market U.S. annual sales of blow-molding products equal about $300 million and consume about 11 billion lb of plastics. Type of plastics by weight is about 65% HDPE, 22% PET, 6% PVC, 4% PP, 2% LDPE, and 1% others. The market breakdown is about 22% food, 20% beverage, 15% household chemicals, 12% toiletries and cosmetics, 8% health, 7% industrial chemicals, 5% auto, and 11% others. Almost 74% of processes are EBM, almost 25% are IBM, and about 1% uses other techniques such as dip BM. About 75% of all IBM products are bioriented. See **blow molding; Coca-Cola bottle; Coor's beer bottle; plastic consumption; plastic-industry machine sales; market.**

blow molding material and equipment variability See **plastic material and equipment variable.**

blow molding material handling See **material handling.**

blow molding melt blockage See **extruder melt blockage.**

blow molding melt-flow orientation See **orientation, accidental.**

blow molding melt-flow oscillation See **melt-flow oscillation.**

blow molding melt-flow test See **test, melt-index.**

blow molding melt-temperature effectiveness See **melt-temperature effectiveness.**

blow molding melt-temperature sensitivity See **temperature sensitivity.**

blow molding melt tracer See **tracer.**

blow molding metal Metal processing is similar to the injection blow molding of plastics except the operation occurs at a higher temperature. Cans are produced in this process, and can be shaped or contoured with different patterns (Crown Cork with Sidel equipment, etc.) See **blow molding, injection; injection molding nonplastic.**

blow molding mold The mold to form hollow parts. It is generally made from aluminum (Al). It can have water jackets, flood cooling, cast-in tubing, and/or drilled cooling lines. The Al provides faster heat transfer than steel. However, steel is also used to improve wear resistance, handling, and life cycle for certain type products and operations. An isolated area, such as a thread or pinch-off, can be steel inserted in Al molds to extend the Al longevity. All molds can include air-ejection systems to remove parts. See **blow molding, extruder-mold; mold; mold cooling, flood; molded-part ejection; mold-material.**

blow molding mold, complex part See **blow molding, extruder three-dimensional.**

blow molding mold contractional obligation See **legal matter: mold contractional obligation.**

blow molding mold cosmetic specification See **molded-part cosmetics.**

blow molding mold dehumidification See **mold dehumidification.**

blow molding mold, preengineered See **mold, preengineered.**

blow molding mold venting See **bleed; venting.**

blow molding operation Most drive systems are hydraulic or hydromechanical hybrid systems with all-electric drives starting to be used. See **drive-system control; injection-molding machine-drive system; injection-molding machine electrical operation.**

blow molding operator's sequence See **operation, manual; operation, semiautomatic; operation, automatic.**

blow molding orientation See **blow molding, stretched.**

blow molding outgassing See **outgassing.**

blow molding parison See **blow molding, extruder, parison.**

blow molding plasticator See **plasticator; screw length-to-diameter ratio.**

blow molding plasticator wobble See **plasticator wobble.**

blow molding plastic consumption See **blow molding market.**

blow molding preform See **blow molding, injection preform.**

blow molding process control See **process control.**

blow molding process-control optimization See **control drive, optimized.**

blow molding process-control safety See **programmable-controller safety.**

blow molding processing See **FALLO approach.**

blow molding processing window See **processing window.**

blow molding product leakage See **container leakage.**

blow molding programmer safety See **programmable-controller safety.**

blow molding product design rule See **design, optimized.**

blow molding purging See **purging.**

blow molding safety See **barrel-venting safety; safety and machines; safety interlock.**

blow molding scrap See **scrap.**

blow molding, scrapless forming See **blow molding, stretched operation specialty; forming, scrapless.**

blow molding screw See **screw.**

blow molding screw puller See **cleaning; extruder screw pulling; injection-molding screw pulling.**

blow molding shrinkage The shrinkage behavior of different thermoplastics and the part geometry. Without experience, trial and error determined what shrinkage will occur immediately at the time of fabrication and what time period is required (usually up to 24 h) to ensure complete shrinkage. Coefficients of expansion and the different shrinkage behaviors depend on whether the thermoplastic material is crystalline or amorphous. Lengthwise shrinkage tends to be slightly greater than transverse shrinkage. Most of the lengthwise shrinkage occurs in the blow-molded wall thickness rather than a body dimension. As an example with behaviors, with polyethylene higher shrinkage occurs with the higher-density plastics and thicker walls. Lengthwise shrinkage is due to a greater crystallinity of the more linear type plastics. Transverse shrinkage is due to slower cooling rates that results in more orderly crystalline growth. Part shrinkage depends on many factors such as plastic density, melt heat, mold heat, cooling rate and uniformity, part thickness, pressure of blown air, and control or capability of the blow-molding production line. See **amorphous plastic; crystalline plastic; design shrinkage; directional property; molding shrinkage; shrinkage; shrinkage block jig; tolerance and shrinkage.**

blow molding starve feeding See **material starve feeding.**

blow molding statistical assessment See **statistical assessment.**

blow molding, stretched High-speed extruder blow molding and injection blow molding take the extra step in stretching or orienting. For example, orientation in a bottle is made almost simultaneously in both the longitudinal and hoop directions. With EBM the parison can be mechanically gripped at both ends of the hot tube in the mold, stretched longitudinally, and blown to provide the circumferential stretching. IBM can be stretched in a similar manner or have a rod within the blown part to apply the longitudinal stretch. Stretched BM was commercially developed and accepted by the market just a few decades ago, with most of the action using IBM.

By biaxially stretching the extrudate before it is chilled, significant improvements occur with savings in heat energy and material consumption. This technique allows the use of lower-grade plastics and thinner walls with no decrease in strength; both approaches reduce plastic material costs. Many plastics have improved physical and improve barrier properties. The process allows wall thickness to be more accurately controlled. Draw ratios used to achieve the best properties in PET bottles (typical 2-to 3-liter carbonated beverage bottles) are about 3.8 in the hoop direction and 2.8 in the axial (longitudinal) direction. These ratios will yield a bottle with a hoop tensile strength of about 29,000 psi (200 MPa) and an axial tensile strength of 15,000 psi (104 MPa). See **acrylonitrile-styrene plastic; Coca-Cola bottle; Coor's beer bottle; ketchup bottle; mayonnaise jar; orientation.**

blow molding, stretched-operation As in non-stretched blow molding, stretched BM has in-line and two-stage processes. With in-line processing, the complete process is done on a single machine. The two-stage requires two machines: one molds the preforms or an extruder producing the tube/parison, and the second takes the preforms or tubes, to be reheated and blown.

Stretch blow is extensively used with PET, PVC, ABS, PS, AN, PP, and acetal, although most thermoplastics can be used. The amorphous types, with a wide range of thermoplasticity, are easier to process than the crystalline types such as PP. If PP crystallizes too rapidly, the product is virtually destroyed during the stretching. Clarified grades of PP have virtually zero crystallinity and overcome this problem. The stretching process takes advantage of the crystallization behavior of the plastics and requires the preform or parison to be temperature-conditioned and then rapidly stretched and cooled into the product shape.

blow molding, stretched-operation specialty Other techniques have been developed to produce stretched bottles/containers with advantages, such as processing at lower temperatures or pressure. They include the dip blow-molding process, where the blow pin dips into a premeasured plastic melt rather than receiving a preform; the melt shot is provided by an injection-molding machine. One technique combines extrusion (single as well as multiple or coextruded film or sheet) and forming (such as thermoforming or compression molding) with the final preform stretched blow-molding operation. The scrapless forming process that uses extruded blanks is also applicable. See **blow molding, compression-stretched; blow molding, dip and displacement; forming, scrapless.**

blow-molding stripping With transparent plastic, or other plastic, with or without graduations, they are coextruded.

blow-molding temperature control See **temperature controller.**

blow molding, three-dimensional See **blow molding, extruder three-dimensional.**

blow-molding temperature See **melt-temperature effectiveness.**

blow-molding troubleshooting See **troubleshooting.**

blow-molding venting See **extruder venting; injection-molding venting; screw, venting; venting.**

blow-molding void See **air entrapment.**

blow molding, volume-adjustment See **blow molding, extruder, bottle volume adjustment.**

blow molding versus injection molding A significant difference exists between blow and injection molding. BM usually requires only 25 to 125 psi (0.17 to 1.03 MPa) pressure, with certain plastics or shapes up to 200 to 300 psi (1.38 to 2.07 MPa). For IM, the pressure is usually 2,000 to 20,000 psi (13.8 to 137.8 MPa) and in some cases up to 30,000 psi (207 MPa). The lower pressure generally results in lower internal stresses in the solidified plastics and usually a more proportional stress distribution. The result is improved resistance to all types of stress (tension, impact, bending, environment). Since only a female cavity mold is required, any changes to be made could literally be half of IM. BM does not permit meeting the tight tolerances achieved with IM. These processes meet different shape requirements. With BM reentrant curved or irregular shapes are easily obtained. With IM the approach is predominantly to make separate parts and in turn assembled (snap fits, adhesives, welded). See **plastic competition; injection molding.**

blow molding wall-thickness control See **sensor.**

blow molding weld line See **weld line.**

blow molding zero defect See **zero defect.**

blown film See **extruder-blown film; extruder-blown film blow-up ratio.**

blow-up ratio The ratio of the diameter of a product such as a blow-molded bottle or extruded blown film to the die orifice diameter. See **extruder-blown film blow-up ratio.**

bluing See **mold bluing.**

bluing agent A substance used to remove yellow light. See **optical brightener agent.**

bluing off See **mold, bluing off.**

blush **1.** The tendency of a plastic to turn white or chalky in areas that are highly stressed, such as the mold gate area during injection molding. Also called *chalking* or *crazing*. See **chalking; crazing. 2.** A fault sometimes found in finished plastic products due to the presence of water, migrating additives, or solvents. See **plasticizer; lubricant bloom. 3.** See **mold-gate blush.**

board foot A unit of quantity equal to the volume of a board 12 × 12 × 1 inches (30.5 × 30.5 × 2.5 cm).

boat **1.** A tungsten container used to hold aluminum during vacuum metallizing. See **metallizing, vacuum. 2.** A marine vehicle that makes extensive use of different types of plastics, including polypropylene and reinforced plastic, that resist salt and fresh waters. See **coating, antifouling; marine application; vinyl seagoing bag.**

body **1.** A nonspecific term approximately synonymous with the terms *consistency* or *viscosity*; usually descriptive of a liquid. **2.** A part having a unique physical property. See **radiation blackbody. 3.** In biochemistry, an agglutinous substance present in blood or tissues. See **chemistry, bio-.**

body putty See **putty, body.**

boiling water See **heat, latent.**

boiling point The temperature of a liquid at which its vapor pressure is equal to or very slightly greater than the atmospheric pressure of the surrounding environment. For water at sea level with 14.7 psi (100 kPa) atmospheric pressure, it is 212°F (100°C). See **atmosphere; heat, latent.**

boiling point, absolute The boiling point of a substance expressed in the unit of an absolute temperature scale. See **temperature, absolute zero.**

boiling pressure See **pressure, boiling.**
bolster See **mold chase.**
Boltzmann, Ludwig (1844–1906) A chemist, born in Vienna whose work became of interest in plastics because of his development of the kinetic theory of gases and rules governing their viscosity and diffusion. Boltzmann's law and principle are still regarded as one of the cornerstones of physical science. See **kinetic theory.**
Boltzmann superposition principle A basis for the description of all linear viscoelastic phenomena. No such theory is available to serve as a basis for the interpretation of nonlinear phenomena—to describe flows in which neither the strain nor the strain rate is small. As a result, no general valid formula exists for calculating values for one material function on the basis of experimental data from another. However, limited theories have been developed. See **kinetic theory; viscoelasticity, nonlinear.**
bomb See **plasticator safety.**
bombardment See **atomic nucleus bombardment.**
bomb effect See **plasticator safety.**
bond breaker See **joining bond breaker.**
bond, chemical See **chemical bond.**
bond, covalent See **electron, Lewis structure.**
bond, de- See **debond.**
bond, heat See **label, heat-transfer.**
bond order See **electron bond order.**
bond, sigma See **electron bond, sigma.**
bond strength The unit load in tension, compression, flexural, peel, impact, cleavage, or shear required in breaking an adhesive assembly with failure occurring in or near the plane of the bond. Also called *adherence.* See **adhesive peel strength; reinforced-plastic peel ply; sandwich peel torque; strength, pull.**
bond, structural See **structural bond.**
bonded abrasive See **abrasive.**
bonded fabric See **fabric bonded.**
bonding **1.** A material or device for binding, uniting, fusing and/or strengthening materials. See **adhesive; fusion; joining; seal; staking; transcrystalline growth; welding; wetting agent. 2.** The joining together of atoms to form molecules. See **atom; chemical reaction; molecule.**
bonding capillary attraction See **capillary attraction.**
bonding, cold See **press, cold.**
bonding, covalent See **covalent bonding.**
bonding, diffusion The assembling or bonding of certain thermoplastic materials without the use of adhesives. When heat and pressure are applied, the plastic chains in the two adjoining thermoplastic layers diffuse into one. See **diffusion.**
bonding forces, molecular See **temperature and molecular bonding force.**
bonding, fusion See **fusion.**
bonding, hot-plate See **welding, hot-tool.**
bonding, hydrogen See **hydrogen atom bonding.**
bonding, induction insert See **insert induction bonding.**
bonding, ionic See **ionic bonding.**
bonding, lap See **joining, lap.**
bonding, metal-to-plastic See **metal-adsorption calorimetry; metal-to-plastic bond.**
bonding, nontacky See **fastener, mechanical non-.**
bonding, peel strength See **adhesive peel strength.**
bonding, secondary The joining together by the adhesive bonding of two or more already cured plastics (reinforced plastics, thermoplastic sheets) and other material parts, during which the only chemical or thermal reaction occurring is the curing of the adhesive itself. See **reinforced plastic cocuring.**
bonding, solvent See **adhesive, solvent.**
bonding, thermocompression The joining together of two materials without an intermediate material by the application of pressure and heat in the absence of an electric current.
bonding, ultrasonic See **sealing, ultrasonic.**
bone ash See **ash, bone.**
bone china Ceramic tableware of high quality in which a small percentage of bone ash is incorporated. The major source for these products is England.
bone surgery See **biological activity.**
bookkeeping See **business bookkeeping; legal matter.**
"book" opening press See **clamping platen, "book" opening.**
Boolean algebra See **computer science and algebra.**
booster See **pressure booster.**
booster, ram See **ram booster.**
boral See **composite, boral.**
borane Binary boron-hydrogen compound. See **boron polymer.**
borate glass See **glass, borate.**
bore **1.** The inside of a barrel, such as a plasticating barrel. See **barrel. 2.** To enlarge a hole with a boring tool, as a lathe or boring mill.
borescoping See **barrel borescoping.**
boron An element that is polymeric, being either amorphous and reactive, or crystalline. Its melting temperature is about 2,300°C (4,172°F). It is almost as hard as diamond and very inert depending on the method of its preparation. It is used in reinforcing plastics. See **fiber, boron; reinforcement.**
boron compound A compound that has numerous applications in the field of polymer chemistry. The largest area of application in this field is for inorganic and organic compounds of boron as catalysts and polymerization.
boron polymer A macromolecule that is formed by polymerization of compounds containing, for example, boron-nitrogen, boron-phosphorus, or boron-arsenic bonds. See **borane.**
borosilicate glass See **glass composition.**
boss See **design boss.**
bossed, de- See **mold cavity, debossed.**

Boston round See **container, Boston round.**
bottle A light-weight container that is made in different shapes to meet different service performance requirements. See **beer bottle; blow molding; blow-molding handle; blow molding; stretched; Coca-Cola bottle; container; Coor's beer bottle; design of the bottle base; energy and bottle; ketchup bottle; legal matter: bottle bill; mayonnaise jar; packaging; polypropylene plastic, transparent blow molding; recycling; waste.**
bottle, carboy A bottle or container that is made of plastic, glass, or metal and is cushioned in a special container.
bottle coating with glass See **barrier, glass coating.**
bottle code system A continuously debatable subject on which progress continues to develop worldwide. For example, a code system to identify the type of plastic used to fabricate a bottle or container was developed to assist waste-treatment facilities. The Society of the Plastic Industry established in 1988 a nationally recognized voluntary system usually located at the bottom of the bottle that has been used for recycling. The three-triangle arrow symbols are used with the plastic abbreviations in its center. The plastics identified include PET, HDPE, LDPE, PP, and PS. See **container code system; recycled plastic identified.**
bottle, collapsible See **design, collapsible-bottle.**
bottle, cryogenically cooled filling Cryogenically cooled PET bottles have been filled at 90° to 93°C (195° to 200°F) or possibly lower instead of the usual untreated 85°C (185°F), with the added benefits of longer shelf life without additional cost.
bottle leakage test See **test, soap-bubble.**
bottle lug **1.** A type of thread configuration, usually with thread segments disposed equidistantly around the bottleneck (finished). **2.** A small indentation or raised portion on the surface of a container provided as a means of indexing the container for operations such as multicolor decoration, labeling, or filling.
bottle manufacture See **blow molding.**
bottle market Markets for plastic bottles include beer, beverage, detergent, juice, hot and cold liquid, food, liquor, wine, health care, and water. See **container market; packaging, beverage-can.**
bottle nipple See **silicone molding compound.**
bottle, opaque milk White pigmented rather than clear transparent high-density polyethylene bottles that are used to protect milk from light, which is said to cause it to lose vitamins and taste. This effect is debatable since the milk is not sufficiently exposed to light to cause degradation. Recyclers report that pigmented plastic is worth about 60% of the natural HDPE plastic.
bottle sealing plane It is the plane on the inside of a bottle cap along the sealing surface.
bottle sorter, optical A device used to separate recyclable plastics such as plastic bottles. Optical sensors are used with mechanical separation of bottles by type of plastic. Systems are used that are similar to x-ray sorting devices. See **recycling, automatic-sorting plastic; sensor, inductive and capacitive proximity; sensor, nuclear.**
bottle standard marine reference material (SRM) Environmental agencies, as well as others studying pollution in the nation's waterways, need materials containing an accurate composition of various compounds as a check to verify the reliability of laboratory instruments and methods. The National Institute of Standards and Technology (NIST) has developed a bottle standard marine reference material (SRM) for this purpose. It contains marine sediment with a wide range of pollutant compounds of interest to environmental scientists. The sediment material, which has certified values of 11 polycyclic aromatic hydrocarbons (PAHS), was collected from the Chesapeake Bay area near Baltimore harbor. It is a dry powder that can be reconstituted into a wet form so that the compounds can be extracted by solvents for organic analysis. See **environment.**
bottle volume adjustment See **blow molding, extruder, bottle volume adjustment.**
bottle weight controller A close-loop control system that adjusts extruder and injection blow molding operations in response to a high-speed bottle-weighing device on the output conveyor.
Bouguer's law The rule that the absorbency of a homogeneous sample is directly proportional to the thickness of the sample in the optical path. Also called *Lambert's law.*
bouncing putty See **putty, bouncing.**
bowed roll See **extruder roll, spreader/expander.**
Bower-Beaman Rule See **glass transition temperature and melting temperature.**
box beam See **design, optimized; design shape.**
Boyle's law See **gas pressure and temperature; van der Waal's force.**
Brabender plasticorder flow See **test, Brabender plasticorder rheometer melt-flow.**
brackish water See **water, brackish.**
braiding See **fiber braided; reinforced-plastic pultrusion, braided.**
branching See **polymer, branched.**
brashiness See **brittle brashiness.**
brass An alloy of copper and zinc used in the manufacture of molds, dies, and instruments. One of its desired and excellent properties is good heat transfer. See *die material; mold material.*
breaker extension See **rupture; tensile strain rupture.**
breaker plate See **screen-pack breaker plate.**
breaking strength See **fracture strength; tensile strength.**
breakout See **fiber breakout.**
breathable film See **packaging, breathable film.**
breathing See **mold breathing; porous, micro-.**
Brewster's constant law See **test, nondestructive photoelastic stress-analysis.**
brick refractory See **refractory, brick.**

bridging **1.** See **screw/barrel bridging. See 2.** See **reinforced plastic pultrusion, shrinkage in. 3.** See **reinforced plastic molding fiber shrinkage.**
brightener See **optical brightener agent.**
brine See **water brine.**
Brinell hardness See **test, Brinell hardness.**
Brintzinger A chemist from Konstanz University, Hamburg, Germany, who in 1982 was the first to report on metalloorganic (metallocene) complex compounds of titanium and zirconium. Science and industry soon used his discovery to develop new polymerized compounds such as polyethylene and polypropylene plastics. Unlike its classical predecessors, the structure of metallocenes can be analyzed in all types of details, enabling it to be adapted to suit the requirements of the plastic researchers with a broad scope of possible variations. See **catalyst, metallocene.**
briquet See **material, briquet.**
bristle **1.** A generic term for a short stiff, coarse fiber. **2.** A term for the hair of the hog.
British thermal unit (Btu) A British thermal unit is the energy needed to raise the temperature of 1 lb of water 1°F (0.6°C) at sea level. As an example, one lb of solid waste usually contains 4,500 to 5,000 Btu. Plastic waste contains greater Btu than other materials of waste. See **calorie; energy consumption; heat.**
brittle Easily broken, damaged, disrupted, cracked, snapped. See **design-failure theory, Griffith; metal fracture.**
brittle brashiness Brittleness resulting from drying or plasticizer migration.
brittle erosion behavior See **erosion behavior, brittle.**
brittle failure A complete fracture of the material in the direction perpendicular to the direction of loading without obvious, uniform cold drawing. See **design-failure theory, Griffith; forming, cold-drawing; fracture, brittle; test analysis, micromechanical.**
brittle-from-ductile transition temperature See **molecular weight, toughness, and temperature.**
brittleness The lack of toughness. Plastics that are brittle frequently have lower impact strength and higher stiffness properties. A major exception is reinforced plastics. See **chemical and physical characteristics; embrittlement; extruder film brittleness; glass transition temperature and brittleness; hydrogen embrittlement; test, nondestructive stress-strain measurement, brittle lacquer technique, toughness; toughness, area under the curve; viscoelastic.**
brittleness temperature The temperature statistically calculated where 50% of the specimens would probably fail 95% of the time when a stated minimum number are tested. The 50% failure temperature may be determined by statistical calculations. See **statistical normal curve.**
brittle point The highest temperature at which a plastic or elastomer fractures in a prescribed impact test procedure. See **test, impact.**
broach **1.** To finish the inside of a hole to a shape usually other than round. **2.** A tool with serrated edges pushed or pulled through a hole to enlarge it to a required shape.
broadgood See **fabric, broadgood.**
brominated See **phosphorous-base flame retardant.**
Bronsted-Lowry acid A substance capable of donating protons. See **acid-base pair, conjugate; proton.**
Bronsted-Lowry base A substance capable of accepting protons. See **proton.**
bronze An alloy of copper and tin, unless otherwise specified. It is used in mold and die manufacture. See **mold material.**
bronze pigment See **color, special-effect; pigment, metallic.**
bronzing **1.** A term sometimes used for *plastic bleeding*. See **bleeding; migration. 2.** The appearance of an iridescent metallic luster caused by a film of dry pigment on a glossy surface.
Brookfield viscometer See **viscometer.**
Brownian movement See **colloidal.**
B-scan See **data, B-scan.**
B-stage See **A-B-C stages.**
Btu See **British thermal unit.**
Bu Informal abbreviation for *bytyl.*
bubble **1.** A void, or globule of gas or air, trapped in a plastic product, usually as a result of faulty processing. See **air entrapment. 2.** In extruded blown (tubular) film production, the tube extending from the die to the nip roll. See **extruded blown film.**
bubble forming See **thermoforming, bubble.**
bubble pack See **packaging, bubble-pack.**
bubbler See **mold cooling channel bubbler.**
buckling See **compression buckling.**
budgeting See **business.**
buffer A material or device placed in a container to position or protect the contents from the forces of impact. Buffers are usually made of a cushioning, corrugated, or compressible foam-type material.
buffer action See **pH buffer action.**
buffer, spectrochemical See **spectrochemical buffer.**
buffing The smoothing of a surface by means of, usually, a rotating flexible wheel that has a liquid suspension, paste, or grease stick form that contain fine, abrasive particles. See **ashing; finishing, ashing and lapping; polish; surface finish.**
building and construction Products (concrete, bricks, sand, etc.) used in these industries represents about 45% of all industrial raw materials consumed worldwide—about the same volume as lumber. In the United States about 20wt% represents plastic consumption. Plastics in this market provide advantages such as performance and endurance, insulation, and cosmetics. See **antimicrobial agent; building and construction market; plastic consumption; plastic growth; plastic properties; Figure 4, Guide to the Plastic House.**

building and construction market The usually reported second-largest market for plastics is building and construction, which consumes about 20wt%, with packaging in first place at 30%. However, the amount of plastics is only about 5% of all materials consumed in building and construction so that a large growth area exists for plastics when the price is right since their properties provide durability. Different plastics that are used include extruded profiles, paneling, insulation, and column support or reinforcing. See **bitumen; building and construction; canopy; Corian; plastic house; plastic markets, product and material; plastic properties; reinforced plastic; vinyl composition tile.**

building and construction sewer rehabilitation See **sewer rehabilitation.**

building material, perlite A form of rock, similar to obsidian, that is mixed with plastics or cement to produce a lightweight building material with good insulation characteristics.

building syndrome, sick See **antimicrobial agent.**

bulk density See **compaction; densification process; density, apparent; density, bulk.**

bulk factor **1.** The ratio of volume of a raw material to the volume of the fabricated part or waste before and after compaction. See **density, bulk; mold; loading well; packing factor; reinforced plastic debulking.** **2.** A term used to describe the volume occupied by a specific weight of material to be processed. See **mold well.**

bulking agent A material or chemical added to another chemical that increases the quantity of the mixture required without changing the chemical activity of the total.

bulk material handling See **conveying, pneumatic; material handling.**

bulk molding compound A high-performance molding compound consisting of short glass fiber with thermoset polyester plastic. Also called *dough molding compound.* See **blender, dough; injection molding, bulk molding compound; mixer-blender with impeller; mold, compression shear-edge; molding, sheet-molding compound and vacuum-press; polyester plastic, thermoset; reinforced-plastic bulk-molding compounding; sheet-molding compound; sheet-molding compound and bulk-molding compound recycling.**

bulk storage Tanks or silos large enough to accept bulk shipments of individual substances. See **storage; storage, silo; warehousing.**

bumper fascia See **automobile bumper fascia.**

bumping **1.** See **mold breathing.** **2.** The uneven boiling of a liquid that is caused by irregular rapid escape of large bubbles of highly volatile components as the liquid mixture is heated.

bun See **foamed bun; foamed sheet stock.**

buna-n Synthetic elastomer/rubber produced by the polymerization of butadiene and acrylonitrile.

buna-s Synthetic elastomer/rubber produced by the polymerization of butadiene and styrene.

bureaucratic dry rot See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

burlap See **fabric, burlap.**

burn See **safety and machines.**

burned A carbonizing condition showing evidence of the plastic's thermal decomposition or degradation through some discoloration, distortion, or localized destruction of the surface. See **fire; flammability.**

burning adiabatically See **adiabatic flame temperature.**

burning rate The tendency of a part to burn at a given temperature. See **flame resistance; flammability.**

burnish **1.** The smoothing of a fabricated part's surfaces by means of tumbling such as using a role mill. See **mill, roll; surface treatment; tumbling.** **2.** To smooth or polish by a rolling or sliding a tool under pressure. See **finish; polish.**

burnishing, grease A modification of the tumbling process used to impart a surface gloss to plastics, particularly castings. A number of products, such as chalk, greasy sawdust, and wax, are used in a tumbler to produce finished parts. See **tumbling.**

burn line A dark streak of decomposed plastic in a product, such as a blow-molded product, caused by improper processing of the plastic.

burn mark An area of degraded or oxidized plastic on or in a molded product that could be due to insufficient cavity venting or improper melting. It shows evidence of thermal degradation through some discoloration on its surface, similar to the action with a burn-line.

burst strength **1.** The ability of a material to withstand internal hydrostatic or gas dynamic pressure without rupture. Hoop stress results from quick burst internal pressure, such as in a pipe or tank. **2.** The hydraulic pressure required to burst a container. **3.** The force required rupturing a material (film, sheet, fabric, etc.) under specified conditions. See **punching device; tear failure; test, burst Mullen; test, dart-drop impact; test, tear-resistance.**

bus A cable used to transmit data from one part of a computer to another between components of the system. See **computer architecture.**

business See **backlog; capital equipment investment; cost; data-management system; entrepreneur; fabricating employment; fabricating outsourcing; gross domestic product; legal matter: agreement not to complete; management crisis; manufacturing execution system; military market; monitoring instances and suppliers; plastic competition; plastic economy; processing; profit; purchase order; to purchase order; blanket; quality auditing; quality control; return in investment; sale investment turn; specification and standard limitation; Variable; wholesaler; World of Plastic Reviews: Thinking Like Manager and Managing for the Long Run.**

business amortization Spreading out cost (capital equipment, tools, plastic materials, etc.) over a period of time.

business bookkeeping An accounting method that clearly shows income, expenses, assets, liabilities, and equity (net worth). The single-entry system is simple and easy to maintain since it basically includes only income and expenses. The double-entry system records total entry transactions and has built-in checks and balances to ensure accuracy and profit-or-loss control. See **A-B-C analysis; backlog; capacity overhead rate; capital equipment investment; computer electronic document and retrieval system cost; economic evaluation method; invest early; profit; project checklist.**

business card, electronic An integrated-circuit business card that has an electronic chip sandwiched between thin layers usually of polyvinyl chloride or ABS plastic. The cards can keep a complete record of transactions that can be useful, such as health care and banking. See **credit card.**

business toll A business that has custom-made products. See **processor, custom.**

butadiene A gas that is insoluble in water but soluble in alcohol and ether. It is obtained from the cracking of petroleum, coal tar benzene, or acetylene produced from coke and lime. It is widely used in the formation of copolymers with styrene, acrylonitrile, vinyl chloride, and other monomeric substances where it imparts flexibility to the processed products.

butadiene-acrylonitrile copolymer elastomer See **nitrile rubber.**

butadiene rubber A synthetic rubber used in plastic compounding such as butadiene-styrene and acrylonitrile-butadiene-styrene.

butt fusion See **welding, hot tool.**

button See **casein plastic.**

buttress thread See **thread, buttress.**

butt wrap See **filament winding butt wrap.**

butyl acetate A solvent that is widely used in the making of photographic films, printing inks, aircraft dopes, adhesives, and coatings. See **solvent.**

butyl acrylate A colorless liquid that is nearly insoluble in water and polymerizes readily on heating. It is used as an intermediate for polymers, copolymers, or organic synthesis.

butyl alcohol A solvent that is used in the fabrication of cellulose nitrate plastics and with urea and melamine formulations for surface coatings. It is also an important solvent for phenol and urea formaldehyde plastic adhesives.

butyl diglycol carbonate A colorless, combustible liquid with a boiling range of 164 to 166°C. It is used as a plasticizer and solvent in lubricants. See **plasticizer.**

butyl epoxy stearate A plasticizer for PVC, imparting low-temperature flexibility.

butyl ether An excellent solvent for many plastics and miscible with most organic solvents. It is stable and has a high boiling point. See **solvent.**

butyl rubber A synthetic elastomer/rubber that is produced by the polymerization of isobutene and other unsaturated hydrocarbons such as butadiene. See **polyisobutylene butyl rubber.**

butyl stearate A mold lubricant and also a plasticizer compatible with natural and synthetic rubbers, chlorinated rubber, and ethyl cellulose. In polystyrene plastic production, it is added to the emulsion polymerization system to impart good melt flow.

butyrate plastic A common name for cellulose acetate butyrate (CAB). See **cellulose acetate butyrate plastic.**

butyrolactone A hygroscopic, colorless liquid used as a solvent for epoxy, cellulosic, and vinyl copolymer plastics. See **solvent.**

buy or lease See **capital equipment investment.**

C

cable See **extruder wire and cable.**
cable coating See **coating.**
cable insulation water treeing The breakdown of cable insulation caused by moisture in the presence of an electrical field.
cable processing See **extruder, wire and cable.**
cable wrap See **orientation and heat-shrinkability.**
cadmium A heavy metal element used as a pigment in plastic. It is being replaced due to its hazardous nature. See **colorant; pigment.**
cage mill See **mill, cage.**
cahutchu See **rubber, natural.**
caking, plastic See **anticaking agent; filament winding cake forming.**
calcined gypsum See **plaster of Paris.**
calcining The heating of inorganic materials to a high temperature but without fusing to drive off volatile matter or to effect changes such as oxidation or pulverization. See **fluid-bed process; fusion; material pulverizing.**
calcite The most common form of natural calcium carbonate. It is used as a filler in plastics. See **calcium carbonate.**
calcium carbide (CaC_2) A soft white mineral (chalk), odorless and tasteless, which when ground and purified is used as a filler or color whitener for plastics. It can also increase toughness of the plastics. The natural form is the calcereous remains of minute marine organisms, decomposed by acids and heat. For large production use, it is made from coal and lime in an electric furnace at 2000°C. It reacts vigorously with water to give ethane. See **acetylene; calcining; fluid-bed process.**
calcium carbonate ($CaCO_3$) The common mineral form of calcite used as a filler and extender. $CaCO_3$ is 98% pure with silica, iron, aluminum, and/or magnesium. It is a nuisance particle dust if not properly handled and contained. This white powder is used in paint manufacture and the manufacture of rubber tires. Also called *ground limestone, marble dust, chalk, whiting,* and *calcite.* See **calcite; chinese white; coral; filler versus unfilled compound; limestone; material, powder; pigment, extended.**
calcium chloride ($CaCl_2$) A colorless, deliquescent powder that is soluble in water and ethanol. It is used as an antidust agent and antifreeze. See **dust; ethylene glycol.**
calcium hydroxide ($Ca(OH)_2$) A white crystal, slightly soluble in water and used in cement, mortar, and the manufacture of calcium salts. Also called *hydrated lime.* See **cement; chemistry, acetylene; lime.**
calcium oxide See **lime.**
calcium silicate ($CaSiO_3$) A naturally occurring mineral found in metamorphic rocks. It is used as a reinforcing filler in thermoset polyester molding compounds, LDPE, and so on. It provides smooth molded surfaces and low water absorption.
calcium sulfate See **gypsum.**
calcium sulfide (CaS) A yellow to light gray powder with the odor of hydrogen sulfide in moist air that irritates people's skin. It is used in luminous paint, as a lubricant additive, and as a floatation agent. See **luminescent pigment; paint.**
calculus The mathematical tool used to analyze changes in physical quantities, comprising differential and integral calculations. It was developed during the seventeenth century to study the four major classes of scientific and mathematical problems of that time: (1) to find the maximum and minimum value of a quantity, such as the distance of a planet from the sun, (2) given a formula for the distance traveled by a body in any specified amount of time, to find the velocity and acceleration of the body at any instant; (3) to find the tangent to a curve at a point; and (4) to find the length of a curve, the area of a region, and the volume of a solid. These problems were resolved by the greatest minds of the seventeenth century, culminating in the crowning achievements of Gottfried Wilhelm (Germany 1646–1727) and Isaac Newton (England 1642–1727). Their information provided useful information for today's space travel. See **atmosphere; mathematics.**
calender A system of large-diameter heated precision rolls whose function is to convert high-viscosity plastic melt into film, sheet, or coating substrates. The calender was developed over a century ago to produce natural rubber products. With the developments of thermoplastics, these multimillion dollar extremely heavy calender lines started using TPs and more recently process principally much more TP materials. The equipment can be arranged in a number of ways with different combinations available to provide different specific advantages to meet different product requirements. See **process control; web.**
calenderette A series of rolls that are used as the hauloff in sheet or film extrusion or a series of rolls used to produce sheet or film. See **extruder flat film; extruder sheet.**
calendering bank calendering See **calender.** See **bank.**
calendering bowl One of a set of chilled cast rolls.
calendering bowl deflection The distortion suffered by calender rolls resulting from the pressure of the plastic running between them. If not corrected, the deflection produces a sheet or film thicker in the middle than the edges.
calendering cleaning See **cleaning.**
calendering coating The coating of paper, textile, or

plastic by calendering. For one-sided coating a calender with three rolls is usually sufficient, although four rolls are frequently used for extremely thin coatings. Double-sided coating can either be done simultaneously on both sides using a four-roll or sequentially by two three-roll calenders. See **calendering-in-train.**

calendering coating, frictional The process whereby an elastomeric compound is forced into the interstices of woven or cord fabrics while passing through calender rolls. See **fabric.**

calendering configuration, roll A configuration of two to seven rolls. The number of rolls and their arrangement characterizes them. Examples of the layout of the rolls are the true L, conventional inverted L, reverse-fed inverted L, I, Z, and so on. The most popular are the four-roll inverted L and Z rolls. The Z calenders have the advantage of lower heat loss in the film or sheet because of the melt's shorter travel and the machine's simpler construction. They are simpler to construct because they need less compensation for roll bending. This compensation occurs because there are no more than two rolls in any vertical direction as opposed to three rolls in a four-roll inverted L calender and so on. See **roll.**

calendering control An automatic web-thickness profile control. See **control actuator; die head, programmed; microprocessor control; process control.**

calendering, controlled nip pressure An adjustable nip or controllability of the nip pressure required to produce products of uniform quality and thickness, with defined properties. Control across the full roll width is achieved by various methods, such as suitable compensation of the deflection of a pair of rolls; mechanical-geometrical compensation, such as roll bending, axis crossing, and crowning of the rolls; and hydraulic compensation systems. Calendering in the manufacture and surface finishing of plastic products, such as nonwovens and woven fabrics, requires roll systems to meet stringent requirements. See **extruder roll; nip.**

calendering cost Lines can start at $1 million. Probably the largest line processing PVC sheet was built by Kleinewefers Kunststoffanlagen GmbH, in Munich, Germany, at a cost $33 million in 1999. It is a 5-roll using L-type configuration. They have 3,500 mm roll-face widths and 770 mm diameters with an output rate at 4,000 kg/h.

calendering credit card See **credit card.**

calendering finish A film or sheet surface that is glazed by means of a calender stack. See **surface finish.**

calendering, foam See **foamed sheet stock.**

calendering, friction A process whereby an elastomeric/rubber compound is forced into the interstices of woven or cord fabrics while passing through the rolls of the calender.

calendering grain The difference in properties lengthwise and crosswise in the calendered film or sheet. Properties in these two directions usually differ—for example, higher tensile strength occurs in the lengthwise direction. See **directional property.**

calendering-in-train The operation of two calenders as a single unit, generally where the first calender coats one side of a material (plastic, fabric, etc.), which is led immediately to the second calender where the other side is coated. See **calendering coating; train.**

calendering lockout See **safety machine lockout.**

calendering material The preparation of the material or compound is usually done by computer-controlled electronic weighing scales that supply precise amounts of each ingredient to a high-intensity mixer. The still-dry, free-flowing blend is then charged to a feed hopper where it is screw fed into a continuous mixer such as an extruder and/or kneader. Under the action of a mixer's reciprocating screw in the confined volume of the mixer chamber, the blend begins to flux or masticate into the required plastic state. Usually the next step is to force it out of the barrel of the mixing chamber through a die producing strands. The strands can exit as a continuous rope or be chopped into small baseball size buns. This hot plastic material may be passed through a two-roll mill and/or be directly conveyed to the top of the calender rolls. The (usual) parallel rolls have extremely flat surfaces and rotate at possibly the same speed but usually at slightly different speeds depending on the plastic being processed. Although plastic forming occurs in the calender itself, down-stream precision cooling rolls operating equipment are needed to produce the thermoplastic film or sheet. See **die; kneading; masticate; mill; mixer; plastic consumption; vulcanization.**

calendering material, frictional coat See **calendering, friction.**

calendering melt tracer See **tracer.**

calendering neck-in See **extruder neck-in and beading.**

calendering optical sheet See **troubleshooting optical sheet.**

calendering or extrusion Two methods of making film and sheet. Factors that govern the advantages and disadvantages of each process can interact in a complex way. Factors to be considered include (1) type of material to be processed, (2) quantity of product to be produced, (3) thickness and uniformity required on film or sheet, and (4) costs. The capital equipment and replacement parts in calendering lines are more expensive. The very small, unsophisticated lines start about the million-dollar range compared to the much lower-cost extrusion lines. In general, plastic materials such as polyethylene, polypropylene, and polystyrene film and sheet are usually produced through the rather conventional extrusion lines. To produce polyvinyl chloride film and sheet in large quantities, calendering is almost always used since the process is less likely to cause degradation than is extrusion and also has dimensional and cost advantages.

A web thickness between 0.002 to 0.020 in. (0.05 to 0.50 mm) is generally the kind of plasticized film and sheeting produced by calender lines. For extremely light gauges, those under 0.001 in. (0.02 mm), calendering could become impractical or damaging to the equipment: for certain materials the thin webs have poor strength and also very high forces can develop on the matting of heavy-duty rolls.

For very heavy or thick gauges such as sheeting over 0.020 in. (0.50 mm), calendering may not be the optimum method of production. There may not be enough shearing action that can be put into the rolling banks to keep the compound at uniform temperature. In addition, the separating forces on the rolls get so low that gauge variations could become prohibitive.

It can be said that basically the upstream and downstream procedures are similar in production lines whether calenders or extruders are used. For a given quantity of output, it is usually necessary to have more extruders than calenders. This situation makes the extrusion lines more flexible and more able to handle relatively short production runs. The extrusion flexibility, when compared to calendering, includes ease of changing product thicknesses, widths, and materials.

Calenders are capable of higher production speeds. Thus, there are situations where they provide a favorable situation for long runs. For these long runs, cost advantages exist. Tolerancewise the calender is easier for producing products that can meet tighter minimum-to-maximum thicknesses on sheets and films. Calendering also provides product uniformity. Constant in-process monitoring and continuous profile adjustments are usually a significant advantage of calendering over other methods.

calendering orientation See **orientation, tenter frame and roll.**

calendering plate-out See **plate-out.**

calendering pressure force Variations in these multimillion dollar calender lines are dictated by the very high force exerted on the rolls to squeeze the plastic melt into thin-film or sheet-web constructions. High force at least up to 6,000 psi (41 MPa) could (if rolls were not properly designed and installed) bend or deflect the rolls, producing gauge variations such as a web thicker in the middle than at the edges. During calendering, particularly film, roll-separating forces in the final nip may be as high as 6,000 psi. This potential problem is counteracted by different methods that include (1) crowned rolls, which have a greater diameter in the middle than the edges; (2) crossing the rolls slightly (rather than having them truly parallel), thus increasing the nip opening at both ends of the roll; and (3) roll bending, where a bending moment is applied to the end of each roll by having a second bearing on each roll neck, which is then loaded by a hydraulic cylinder. Controls are used to perform any roll bending and crossing of the rolls.

calendering programmable controller safety See **programmable-controller safety.**

calendering roll See **calendering configuration, roll.**

calendering safety Various safety devices are used in different sections of the calender, from start to the end of the line. Material being fed into compounding/mixing machines includes safety devices that protect people and the machines (by eliminating contaminants, for example) and a safety bar that is located at the nip ("bite") of the rolls. See **nip; safety.**

calendering, sheet A sheet obtained from a calender. See **extruder sheet.**

calendering temperature sensitivity See **temperature sensitivity.**

calendering web See **web.**

calendering, Z A calender with four rolls arranged so that the plastic material being processed passes through them in the form of the letter Z.

calendering zero defect See **zero defect.**

calibration **1.** A comparison of the indication or output of a measuring device with respect to that of a standard. **2.** The setting of individual instruments and component devices to give the precise output needed for correct processing operations.

Calibre Dow Chemical's trade name for its family of polycarbonate plastics.

caliper A measuring device, such as a micrometer, that has a graduated scale for exact measurement. See **measurement.**

calorie The amount of heat needed to raise 1 g of water 1°C at 1 atm. The abbreviation for calorie is *C* or *cal*; when identifying kilogram calories use *kcal*. See **British thermal unit; energy consumption; energy efficiency; heat.**

calorimeter An instrument capable of making absolute measurements of energy deposition (or absorbed dose) in a material by measuring its change in temperature and imparting a knowledge of the characteristics of its material of construction. See **adiabatic calorimeter; differential scanning calorimetry; energy absorption; radiation dosimeter, primary standard.**

calrod heater See **thermoforming heater, metal-sheathed.**

camelback See **rubber tire camelback.**

camphor An important plasticizer for cellulose nitrate. It occurs naturally in the wood of camphor trees or can be produced synthetically.

CAMPUS database This computer-aided material preselection by uniform standards of testing method (software) compares different plastics available from different material suppliers. Special CAMPUS pages are on suppliers websites and are updated each time they finish further testing of new materials. Its data can be directly merged into computer-aided engineering programs. CAMPUS provides comparable property database on a uniform set of testing standards on materials along with processing information. The database contains single-point data for mechanical, thermal, rheological, electrical, flammability, and other properties. Multipoint data are also provided such as viscosity versus shear rate at multiple temperatures, secant modulus versus strain, and tensile stress-strain over a wide range of temperatures. See **computer-aided engineering; plastic material selection.**

Canada melt flow test See **test, Canadian melt flow.**

can, beverage See **bottle; container; packaging, beverage-can.**

candela The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{-12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian. See **geometric steradian; luminous flux; measurement; radiation, monochromatic.**

canopy **1.** An ornamental rooflike structure that includes transparent or translucent plastic enclosures in shapes such as blisters, corrugations, and ribbing. See **building and construction market.** Canopies are transparent enclosures over an airplane cockpit. See **injection-molding aircraft canopy; transparent. 2.** The lifting or supporting surface of a parachute; usually made of woven nylon fibers and nylon major support cords.

canopy, rain-forest Small to very large enclosures where people or vegetation exist in a controlled atmosphere. Transparent large plastic panels are usually used supported by geometric reinforced plastic frames. See **rain erosion; reinforced plastic; transparent plastic.**

cantilever beam See **flexural testing; test, deflection temperature under load.**

cantilever, snap-fit See **design, snap-fit.**

cantilever, spring See **design, spring.**

canvas See **fabric, canvas.**

capacitance See **electrical capacitance.**

capacitor coating See **parylene plastic.**

capacity overhead rate See **business bookkeeping; capital equipment investment; economic evaluation; production capacity overhead rate.**

capillarity The attraction between molecules, similar to surface tension, that results in the rise of a liquid in small tubes or fibers, as can occur in filled compounds or reinforced plastics. See **condensation, capillary; drying, capillarity; rheometer, capillary; viscometer, capillary.**

capillary attraction The force of adhesion or bonding between a solid and a liquid in capillarity. See **adhesive.**

capital and inventors In 1871 Simon Ingersoll, an inventor with many patents, including rock-drill mining patents, considered himself a pure inventor who was part of a necessary equation for the advancement of technology. He wrote that to put over a new thing in the interest of the human race, it is necessary for some individuals to go "crazy" over a subject. It is equally important that (usually) someone else should furnish the money. Thus, this combination of a crazy inventor and capital equals the elements necessary to success.

capital equipment investment When a plant is to purchase equipment, a buy, loan, or lease can be used. Many factors influence the final decision, such as new equipment that processes materials at a faster rate then the old equipment did. If cash is used to purchase faster equipment, then additional cash will be required to purchase more material, possibly more handling equipment, storage facilities for materials and products, and so on. Determining the true cost of each investment is based on developing the proper comparisons. If the comparison is based on total costs, then the usual way to go is cash. If cash is not available, then a loan is a consideration. Those with low tax rates or investment credit-absorption limitations could find leasing more attractive: (1) usually it is more costly to lease, (2) but cash outlay and down payment could be eliminated, (3) borrowing capacity increases, (4) it may be a way to gain additional assets, and (5) it shifts obsolescence from lessee to lessor. There are noneconomic factors to consider, and whatever action is taken, a risk factor is involved. See **business bookkeeping; economic evaluation; equipment; Euro and European Community; invest early; legal matter; warranty; machine aging; production capacity overhead rate; profit; sales investment turn.**

capital equipment investment tax credit A direct credit against the federal income tax that is allowed, generally, at 10% of the purchase cost with depreciable life greater than seven years.

capping See **coextrusion capping.**

caprolactam See **polycaprolactam plastic.**

capstan See **extruder wire and cable capstan.**

cap, tamper-proof See **mold, collapsible-core.**

captive processor See **processor, captive.**

car See **automobile, composite.**

carbazole White crystals, insoluble in water, obtained from ortho-amino-diphenyl and used in the production of polyvinyl carbazole plastics.

carbide A binary solid compound of carbon and another element. Familiar types include calcium, tungsten, silicon, boron, and iron. See **fiber, silicon carbide.**

carbon An element that provides the backbone for all organic polymers. It is a nonmetallic element occurring freely as a diamond, graphite, or coal. See **chemical composition and properties of plastic; element; mole.** Graphite is a crystalline form of carbon. Diamond is the densest crystalline form of carbon. See **mesophase.**

carbonaceous matter The component of a fuel, including solid waste, that consist of pure carbon or its compounds, usually associated with the residue of incineration. See **energy reclamation; incineration.**

carbon, activated A family of carbonaceous substances manufactured by processes that develop adsorptive properties. See **adsorption.**

carbon adsorption See **pollution; water.**

carbonated beverage bottle See **blow molding, stretched; bottle; Coca-Cola bottle.**

carbon atom linkage See **molecular structure configuration.**

carbon black A black colloidal carbon filler made by the partial combustion or thermal cracking of natural gas, oil, or other hydrocarbon. Depending on the starting material and method of manufacture, different forms with different properties are produced that are extensively used as additives, fillers, and pigments. Because carbon black possesses useful ultraviolet protective properties, it is used extensively in plastics for outside weathering applications such as wire coating, containers, black agricultural film or sheet, and water piping. Usage in plastics and rubbers can be divided into the basic categories such as filler, colorants, stabilizers, electrical conductors, and weather proofing. Also called *acetylene black, channel black, furnace black,* and *gas black.* See **additive; material, powder; pigment, reinforcing; ultraviolet stabilizer.**

carbon black, animal A finely divided carbon made of animal bones or ivory. It is used for pigments, decolorizers, and purifying agents. See **decolorizing agent; purification.**

carbon black, conductive A specialized porous carbon black with a very high surface area that is used for shielding and grounding electric and electronic thermoplastic parts. This conductive additive also can be used to make black TP parts paintable by the electrostatic methods. Parts such as black automobile bumpers and side panels usually have to be painted separately from the rest of the car when using conventional carbon black resulting in extra costs and potential noticeable color differences. The porous black additive makes the plastic conductive, permitting parts to be electrostatically painted without sacrificing mechanical properties. When loaded with large amounts of solid acetylene carbon black or other conductive materials, loss in properties occur (flexibility, impact resistance). See **coating, electrostatic spray; electromagnetic interference.**

carbon-carbon composite A composite such as carbon fiber with a carbon matrix. See **composite.**

carbon dioxide (CO_2) A colorless, odorless gas made, for example, by passing air over red-hot coke. It is an important intermediate in the production of many plastics. It is used in different fabricating processes in place of air or other gases providing heat, resulting in reduced molding-cycle time. See **autoclave nitrogen atmosphere; blow molding; decomposition, digestion; finish system, reduce-solvent; foam and blowing agent; foamed-blown CO_2.** It is used for cleaning metals (dies, molds) to remove plastics by blasting with rice-sized pellets of dry ice (CO_2) at 40°C (104°F). The residue is removed in a process often compared to sand blasting without the sand. Ice-blasting equipment is small and uses shop-compressed air. CO_2 crystals exert strong thermomechanical force on impact. Parts can be cleaned while hot and in the machine. With heat, they clean faster. See **cleaning; finish system, reduce-solvent; ice, dry.** CO_2 improves plastic processing and properties resulting primarily from the lack of chain transfer and urgency for high plasticization. Liquid and supercritical CO_2 is used as a continuous phase in reducing polymerization reactions. The plastics industry's driving force in these developments is to reduce volatile organic compounds such as polychlorofluorocarbons and reduce the generation of aqueous waste streams. See **decomposition, digestion; polymerization; volatile organic compound.**

carbon dioxide autoclave curing See **autoclave nitrogen atmosphere.**

carbon disulphide (CS_2) A colorless, odorless gas for plastics, rubbers, and sulfur. It is an intermediate in the production of viscose rayon (a sulfide used as a solvent in paint removers, rubbers, and so on). See **fiber, rayon viscose.**

carbon filler See **fiber, carbon; fiber, graphite; fiber, graphite and carbon characteristic.**

carbon filler The family of fillers that is based on carbon in various forms, such as carbon black and graphite. Its use includes providing a black pigment, improving plastic's lubricity during processing and part performances, and increasing electrical conductivity of plastics. Also called *powdered carbon* or *carbon powder.*

carbonization Process of pyrolyzation in an inert atmosphere at temperatures that start at 800° to 1,600°C (1,470° to 2,910°F) and higher—usually about 1,315°C (2,400°F). Temperature is influenced by precursor, manufacturing processing capabilities, and properties desired. Basically, carbonization is the charring from the loss of side components, leaving only the carbon from the precursor plastic. See **ablation; pyrolyzation.**

carbonization See **pyrolyzation.**

carbon monoxide (CO) A colorless, poisonous gas that is soluble in water and used in the production of products such as formaldehyde and methyl alcohol. It can be produced during incomplete combustion (burning fumes such as automobile exhaust) or microbial decomposition of solid wastes in oxygen-limited atmospheres. See **combustion.**

carbon tetrachloride A colorless liquid with a sweet odor whose use includes chlorination of organic compounds. It decomposes to phosgene at high temperatures. Also called *tetrachloromethane* or *perchloromethane.* See **phosgene.**

carborundum An artificial abrasive made from carbon and silicon. Its use includes as filler in plastics. See **filler.**

carboxymethylcellulose plastic (CMC) A water-soluble plastic that is harmless for external body contact or ingestion (edible). It is used in creams or foods as a thickening agent. See **methylcellulose plastic; plastic, water soluble.**

carcass See **belting.**

carcinogen A substance that is reported to cause or contribute to cancer. See **ISO-10993 certification.**

carded package, blister See **packaging, blister.**

carding See **fiber carding.**

card, smart A card that embeds semiconductor computer chips between two printed acrylonitrile-butadiene-styrene (sheet) labels by injecting ABS between the labels to form 0.8 mm thick smart cards. See **business card, electronic; calender; credit card.**

Carilon Shell Chemical's trade name for its semicrystalline aliphatic polyketone plastics.
carnauba wax A hard, natural wax obtained from South America palm trees. It is used in the plastics industry as a lubricant, a modifier, and in polishes. See **wax.**
carousal clamp See **clamping platen, rotary.**
carpet coating See **powder coating.**
cartridge heater See **heater, cartridge.**
case hardening See **hardening, case.**
casein A natural protein material precipitated from cow's skimmed milk and also from soya or similar beans by the action of either rennet or dilute acid. Rennet casein has found its main application in plastics. Acid type has gone into different products including adhesives. See **rennet; zein plastic.**
casein plastic A tough, nonflammable thermoplastic or thermoset plastic based on casein. The most popular is produced by reacting formaldehyde with casein to produce a slightly flexible TS of good impact strength but poor dimensional stability and resistance to water. Used in the manufacture of products such as buttons, beads, and buckles. Casein will react with aluminum salts in water solution to produce casein-alum, a thermoplastic capable of being molded or extruded as rods or tubes. Also called *casein-formaldehyde.*
cashew plastic A thermoset plastic produced from the phenolic fraction of cashew nut shell oil.
cash flow See **capital equipment investment.**
cash-flow uncertainty See **economic evaluation reliability.**
CASING See **surface CASING.**
CASSIS software See **legal matter: patent search.**
cast To form a plastic product. See **casting.**
castable polyurethane elastomer See **additive chain extender.**
casting A two-component system that does not involve pressure or vacuum, although certain plastics and/or complex products may require low pressure or vacuum casting. Generally plastics that are free-flowing and have low surface tensions with low viscosities are used for castings of intricate shapes and fine detail in design. Low-viscosity plastics are also more suitable for producing bubble-free castings. However, high-viscosity systems usually produce better physical properties. See **air entrapment; embedding; reaction injection molding.** A part is formed by pouring a fluid monomer-plastic into a mold cavity. Based on the mixture prepared, polymerization takes place in a set time. By using an open or closed mold, the part shape is formed. Pouring the liquid plastic onto a moving belt can produce a cast film. Also called *embedding, potting, molding, impregnation,* and *encapsulation.* See **burnishing, grease; coating; cast; decorating; encapsulation; extrudey flat film; film; film, cast; foamed casting; foundry plastic; foundry shell molding; in pregnation impregnation trickle; iron, cast; mold cavity; polymerization; bulk; processing window; notational molding; soluble-core molding texturizing; zinc.**
casting, acrylic-sheet Since the 1930s cast polymethyl methacrylate sheeting has been made by polymerization of MMA in a cell assembled from two glass plates and a flexible gasket. Sheeting is also made continuously by extrusion casting, using in a stainless steel belt on which polymerization is completed. Continuous is not as optically clear as casting. See **acrylic plastic.**
casting, air-entrapment See **air entrapment.**
casting, centrifugal A method of forming plastic in which a dry or liquid plastic is placed in a rotating mold such as a pipe. As it rotates around a single axis, heat is applied to the mold. The centrifugal force induced will force the molten plastic to conform to the configuration of the inside mold cavity. This method is different than rotational molding since it rotates only around one axis. Also called *centrifugal molding.* See **coating, centrifugal or rotational; powder coating; rotational molding.**
casting, dip A process of submerging a hot molded shape, usually metal, into a fluid plastic. After removal and cooling, the product around the mold is removed from the mold. Also called *dip coating* or *dip molding.* See **blow molding, dip and displacement.**
casting heat, exothermic With room-temperature heat-curing systems, additives or promoters are used to provide the necessary heat through chemical reactions. This reaction has to be controlled so that overheating will not occur, particularly with large parts. See **exotherm.**
casting, investment A method developed by early Egyptians to make jewelry where sculpture wax was dipped in a ceramic slurry and then dried and heated to remove the wax. In turn, the ceramic cavity received molten metal to form the desired finished part. This technique continued to be used with modifications that initially led to the so-called lost-wax or soluble-core wax molding (which started during the early 1940s). Later, low-melting eutectic alloys were used providing a means to high-production complex molding (injection molding, etc.). See **eutectic mixture; reinforced plastic molding, lost-wax; soluble-core molding.**
casting, liquid The pouring of liquid plastic or elastomer into molds and then allowing it to cure to a solid form. Thermoset plastics, such as epoxy, polyurethanes, and silicones, are commonly used. Technically refined versions of this old process makes it a reliable and cost-effective choice for different products such as electronic and ornamental encapsulation, cardiac pacemaker encapsulations, hand-held optical devices, and so on. New developments in the basic three material types and process control specifically for liquid casting have extended the use of this process. See **casting.**
casting, slush molding A method where thermoplastics in liquid form are poured into a hot mold, stationary or moving and a viscous skin forms. The excess slush is drained off, the mold is cooled, and the molding stripped

out. The method is used to produce rain or snow boots, auto instrument panels, overshoes and corrugated and noncorrugated complex tubes, caps, and other shapes. Also called *slush molding* or *cast molding*. See **powder molding; rotational molding.**

casting, solvent A solvent form of a plastic compounded with its constituents (stabilizers, additives, plasticizers, etc.) and carefully prepared at a certain rate of mixing. Soluble plastics are poured into a mold (to mold parts) or on a moving belt (to form film) where heat is applied using heat-control zones to prevent formation of blisters. The rate of solvent evaporation is inversely proportional to the square of the thickness. To reduce cost and meet regulations, solvent recovery systems are used that have explosive-proof hazard safety capabilities. There are also systems that use water-based solvent solutions such as polyvinyl alcohol plastic. See **blister; film, cast; hazard; solvent.**

casting, spin A process that uses easily adjustable centrifugal force to inject liquid thermoset plastics into a circular disc-shaped elastomeric mold under pressure, completely and rapidly filling the mold cavities. Spin casting using plastic molds, such as silicone, is used to produce close tolerance, highly cost effective, limited production in a variety of materials.

casting, vacuum A casting process in which a vacuum is required to withdraw air from the different casting materials before they harden or cure and that is designed to prevent air-bubble defects in the finished product.

Catalloy process See **polypropylene, multiple monomer.**

catalyst A phenomenon in which a relatively small amount of substance augments the rate of a chemical reaction without itself being consumed, and is recovered in unaltered form and amount at the end of the reaction. It generally accelerates the chemical change. The materials ordinarily used to aid the polymerization of most plastics are not catalysts in the strict sense of the word (they are consumed), but common usage during the past century has applied this name to them. See **accelerator; alumina, activated; antimony trioxide; boron compound; chemical reaction; dicyandiamide; hardener; inhibitor; molecular sieve; promoter; vanadium trioxide.**

catalyst, acidic See **zinc nitrate.**

catalyst, aluminum alkyl A catalyst used in the Ziegler-Natta process. See **catalyst, Ziegler-Natta.**

catalyst, auto- A catalytic reaction induced by a product of the same reaction. This action occurs in some types of thermal decomposition.

catalyst, benzoyl peroxide A white, granular, crystalline solid. It is tasteless, has a faint odor of benzaldehyde, has active oxygen, and is soluble in almost all organic solvents. It is used as a polymerization catalyst with different plastics such as thermoset polyester, rubber vulcanization without sulfur, and embossed vinyl floor covering. See **extruder wire and cable cross-linking PE with peroxide; polyester plastic, thermoset.**

catalyst carrier A neutral material that is used to support a catalyst, such as activated carbon, diatomaceous earth, or activated alumina.

catalyst converter See **incineration fume system.**

catalyst coordination See **catalyst, Ziegler-Natta.**

catalyst cracking See **zeolite.**

catalyst, enzyme An organic catalyst formed by living tissue. Because microorganisms are able to synthesize thousands of complex organic molecules, they represent an enormous catalytic potential to the industrial chemist. A remarkable aspect of enzymes is their enormous accelerated catalytic power; they can enhance reaction rates by a factor of from 10^8 to 10^{20}. Also they can function in dilute aqueous solution under moderate conditions of temperature and pH. See **biodegrading microorganisms; waste; zymoplastic.**

catalyst, fluid Finely divided solid particles utilized as a catalyst in a fluid-bed process using certain thermoset plastics. See **coating, fluidized-bed.**

catalyst, metallocene A substance that has a uniform molecular weight that effectively eliminates molecular extremes, resulting in a range of mechanical, physical, and chemical property improvements, processing advantages, and lower costs. Metallocene catalysts achieve creativity and exceptional control in polymerization and product design, permitting penetration of new markets and expansion of present markets. They can model and predict plastics structural products in a matter of days rather than years. Emphasis has been on the polyolefins (mPOs); others include PS, PE/PS, TPO, and EPDM. Uniquely synergistic combinations of complementary abilities include mPE, which becomes an economical material competing with the properties of nylon and thermoplastic polyester plastics. Also one can produce mLLDPE film with the same strength at a lower gauge than conventional LLDPE because of its narrow molecular weight range. These Me catalysts are more accurate in characterizing plastics than today's quality control instruments can verify. Also called *single site, Me,* and *m.* See **Brintzinger; interpenetrating network.**

They produce plastics that are stronger and tougher, so less plastic is required. They process in a different manner, and have unique processing techniques. The target is to obtain a plastic with a specific molecular weight distribution (MWD), density, melt-flow rate, tensile strength, flexural modulus, or a combination of other factors. Whatever the parameter, Me catalysts allow fabricators to alter reactor temperatures, pressures, and other variables to achieve their goal. Regardless of density or comonomer, mPO grades can combine softness and toughness, whereas conventional POs must trade off one for the other.

These catalysts can make plastics that process well by knitting long branches into the carbon chains. They make plastics with uniform, narrow MWD, high comonomer content, very even comonomer distribution, and an enormously wide choice of comonomers compared to multisite Ziegler-Natta catalysts. Comonomer choices include aromatics, styrene compounds, and cyclic olefins. Copolymers made with conventional Z-N catalysts favor ethylene and propylene. They incorporate only isolated amounts of more exotic monomers. The Me catalysts have been used to make different plastics such as PE homo-, co-, or ter-polymers from 0.865 to 0.96 density; isotactic, syndiotactic, and atactic PP; syndiotactic PS; and cyclic olefin copolymers. See **catalyst, Ziegler-Natta; comonomer.**

catalyst, metallocene, processing As an example, blown-film extruders designed to process LLDPE can process mLLDPE generally without difficulty; torque, head pressure, and motor load limitations generally do not limit film productivity. However, it is important to understand the differences arising from the different rheologies. The mLLDPE has a narrower MWD, and it thus exhibits lower shear sensitivity. The extruder would operate at higher temperatures and motor torque levels, while decreasing bubble stability and easing tensions on winding and drawdown ratio. The Me with less chain branching would result in faster melt relaxation and less draw resonance. One with lower density would have greater elasticity, decreased specific rate in a grooved feed machine, and increased specific rate in a smoothbore machine, while harder to wind.

All other things being equal, they are more viscous at typical extrusion shear rates than conventional LLDPE. There is a difference between shear rheology with the same screw/barrel. The mLLDPE will extrude at a higher melt-temperature profile. This action may limit output on cooling-limited lines, but it may be possible to keep line speeds constant. The result is a thinner film having the same performance because of the better properties offered by mLLDPE. Barrel cooling can be used to reduce mLLDPE melt temperatures, but it may be more desirable to optimize the extruder screw for the plastic's rheology.

catalyst, metallocene, Z-N comparison Catalysts are important keys to plastic manufacture and production. The long-established Ziegler-Natta catalysts as well as the more recently discovered metallocene catalysts (m or Me catalysts) are used to synthesize polyolefins and other plastics. A difference is that polyolefins produced with Z-N exhibit randomly arranged, comparatively short side chains. Me gives rise to polyolefins with a tailor-made side chain length (up to entire polymer chains) and a defined side chain distribution. See **catalyst, Ziegler-Natta.**

catalyst, negative A catalytic reaction such that the reaction is reduced by the presence of the catalyst; it is an inhibitor, retarding agent that reduces the speed of a chemical reaction. See **inhibitor; retarder.**

catalyst organotin See **foamed polyurethane.**

catalyst, physical A radiant energy that is capable of promoting or modifying a chemical reaction.

catalyst, polymerization See **polymerization catalyst.**

catalyst, redox See **redox.**

catalyst selectivity **1.** The relative activity of a catalyst in reference to a particular compound in a mixture. **2.** The relative rate of a single reactant in competing reactions.

catalyst, single-site A substance that is used to produce plastics with different, improved properties. See **polymerization catalyst; polypropylene plastic.**

catalyst, stereospecific An organometallic catalyst, such as the Natta catalyst, that permits control of the molecular geometry of plastic molecules.

catalyst type A catalyst that is usually used for specific chemical reactions. Types include Ziegler-Natta, metallocene, borealis, DuPont, Lyondell, and Sclair, with combinations of certain catalysts. See **plastic competition.**

catalyst, zeolite A silicate that is made with controlled porosity. It is used as a catalytic cracking catalyst in petroleum refineries or a loaded catalyst for other chemical reactions. See **zeolite.**

catalyst, Ziegler-Natta Karl Zeigler (1898–1973) of Germany and Giulio Natta (1903–1979) of Italy developed a catalyst for the industrial production of plastics. Together they received the Noble Prize for chemistry in 1963. They provided the key (Zeigler for polyethylene, Natta for polypropylene) at that time to a relatively simple, inexpensive, and controllable large-production method. They also paved the way for the overwhelming triumph of the polyolefins in subsequent years. All this is now changing, to some degree, with the metallocene catalysts. Unlike the Z-N, the new generations of catalysts provide undreamed of and very simplified production capabilities that produce improvements in properties, processability, and cost. Also called the *Z-N catalyst.* See **polymerization, Ziegler-Natta.**

catalytic The action involving or relating to a catalysis reaction. Examples are the catalytic cracker in a petroleum refinery in which cracking of fuel is carried out in the presence of a catalyst, and catalytic systems that recover waste such as toxic materials and others. See **condensation agent; heating, catalytic; polymerization, catalytic; thermoforming heater, catalytic gas; catalytic converter.** See **incineration fume system.**

catastrophic failure See **failure, catastrophic.**

catenary See **festoon; roving catenary.**

catheter See **medical catheter.**

cathode ray tube (CRT) The most widely used visual display—essentially a television screen. In its manufacture, it consumes all types of plastics to meet all types of requirements. See **computer A-scan.**

cathode sputtering See **coating, sputtered.**

cationic polymerization See **polymerization, cationic.**

cationic reagent One of several surface-active substances in which the active constituent is the positive ion. It is used to flocculate and collect substances that are not flocculated by oleic acid or soaps. See **flocculation.**

cat's-eye See **fish-eye.**

catsup bottle See **ketchup bottle.**

Cauchy-Riemann differential equation See **design, melt-flow Cauchy-Riemann differential equation.**

caulking compound A soft plastic consisting of pigment and vehicle used for sealing joints in buildings, boats, and other structures where normal structural movement may occur. Compounds retain their plasticity for years; some can last for centuries. Life expectancy is based on composition. Techniques such as knife or gun (miniextruder) can apply them. See **design sealant joint shape; plastic, hydrocarbon; putty, body.**

caul plate A thin sheet free of surface defects, usually aluminum, the size of press platens used in hot pressing material (laminate, reinforced plastics, layered film, etc.). See **laminate.**

cavitation The emulsification produced by disruption of a liquid into a liquid-gas two-phase system, when the hydrodynamic pressure of the liquid is reduced to the vapor phase. It is the formation and collapse, within a liquid, of cavities or bubbles that contain vapor or gas, or both. To erode a solid surface by cavitation, it is necessary for the cavitation bubbles to collapse on or close to the surface. In general, cavitation originates from a decrease in static pressure in the liquid. It is distinguished in this way from boiling, which originates from an increase in liquid temperature. When compared to metals, plastics provide protection to cavitation erosion. See **erosion; porosity; test, cavitation erosion.**

cavitation cloud A collection of a large number of cavitational bubbles. The bubbles in a cloud are small, typically less than 1 mm (0.04 in.) in cross-section. A cavitation cloud usually obscures a surface that is being eroded by cavitation.

cavitation erosion The progressive loss of original material, particularly steel, from a solid surface due to continued exposure to cavitation due to rapidly moving fluid. Erosion may occur in either internal flow systems such as piping, pumps, and turbines or in external flow systems such as ship propellers. The phenomenon of cavitation was identified as early as 1873. To protect against cavitation erosion use is made of hardened materials, chromium, and plastic coatings. See **erosion; test, cavitation erosion; test, nondestructive ultrasonic; wear.**

cavity See **cavitation; foam cell; mold cavity.**

C-blade mixer See **mixer, sigma blade.**

Cefor Shell Chemical's trade name for its family of polypropylene-butane plastics.

cell **1.** A single cavity formed by gaseous displacements in a plastic material that forms cellular or foamed plastic. Each of the single small cells is surrounded completely or partially by walls of plastics. See **foam and process cell structure; foamed cell.** **2.** In solid waste disposal, the holes into which waste is dumped, compacted, and covered with layers of dirt on a daily basis. See **waste.**

cellophane A transparent cellulose plastic material made by mixing cellulose xanthate with a dilute sodium hydroxide solution to form a viscose. Extruding the viscose, in sheet form, into an acid bath creates regenerated cellulose. In the past it was widely used as a packaging and overwrapping material; polyethylene and other polyolefins have replaced practically all the cellophane in packaging applications. Also called *regenerated cellulose.* See **cellulose plastic; fiber, rayon; viscous process.**

cellular concrete A lightweight product consisting usually of Portland cement, cement silica, cement-pozzolan, or lime-silica pastes containing foaming agents to produce voids or cell structures. Autoclave curing is usually used. Different binder ingredients are included to provide different properties. Plastics are used to provide color and meet service resistance such as weathering conditions. See **concrete.**

cellular elastomer See **foamed elastomer.**

cellular material See **foam.**

cellular plastic, syntactic See **reinforced plastic, syntactic cellular plastic.**

cellular telephone See **printed circuit board, surface-mounted technology.**

celluloid See **cellulose nitrate plastic.**

cellulose A natural carbohydrate polymer of high molecular weight comprised of long chains of D-glucose units. It is derived from plants such as cotton and trees. $C_6H_{10}O_5$ is the main polysaccharide in living plants, forming the skeletal structure of the plant cell wall. Cotton is almost pure cellulose. It is the main constituent of dried woods, jute, flax, hemp, and ramie. It is used in producing cellulose esters and ethers (cellulosic plastics and fibers), but its largest use is in paper manufacture. It is found in plastic, textiles, and paints. Also called *pulp, cellulose pulp,* or *alpha cellulose.* See **cellophane; fiber linter.**

cellulose I The crystalline modification of cellulose that normally occurs in nature.

cellulose II The crystalline modification of cellulose that is found in mercerized cellulose, in regenerated cellulose, and in cellulose produced by the hydrolysis of various cellulose derivatives.

cellulose III A crystalline modification of cellulose produced by treatment, under certain conditions, with ammonia or sometimes amines. The method of removing the reagent determines the modifications produced.

cellulose IV A crystalline modification of cellulose produced by heat treatment of cellulose II.

cellulose acetate butyrate plastic A thermoplastic that is similar to cellulose acetate plastic and has improved processability, toughness, moisture resistance, and dimensional stability. Also called *CAB, cellulose butyrate,* or *butyrate plastic.*

cellulose acetate fiber An acetyl derivative of cellulose. Triacetate designation can be used when not less than 92 percent of the cellulose groups are acetylated.

cellulose acetate phthalate plastic A mixed ester of cellulose containing both acetate and phthalate groups.

cellulose acetate plastic (CA) A member of the cellulosic group of thermoplastics made by treating cellulose with acetic acid and acidic anhydride in the presence of a catalyst. They are extremely tough and have good impact resistance, stiffness, hardness, "feel," and electrical and dielectric properties. CA when compounded with suitable plasticizers provides tough TP materials. They are available in a wide range of colors. This TP has poor resistance to solvents, alkaline materials, and fungi; high moisture pickup and permeability; low compressive strength; and high flammability. Also called *CAC.* See **acetate.**

cellulose acetate plastic process Acetylation of cellulose (wood pulp or cotton linters) with acetic acid or acidic anhydride and sulfuric acid catalyst to produce cellulose acetate plastics or fibers.

cellulose acetate propionate plastic (CAP) A thermoplastic that is similar to CAB but made with propionic anhydride. Usually called *cellulose propionate.* See **cellulose propionate plastic.**

cellulose, alpha A very pure cellulose prepared by special chemical treatment. The major components are wood and paper pulp. It is used as filler in different plastics. See **paper.**

cellulose, bamboo See **bamboo.**

cellulose, cork See **cork.**

cellulose derivative A substance derived from cellulose by substitution of one or more of the hydroxyl groups with some other radical. Most derivatives are ethers or esters.

cellulose ester plastic A derivative of cellulose in which the free hydroxyl groups attached to the cellulose chain have been replaced wholly or in part by acidic groups. Esterification is effected by the use of a mixture of an acid with its hydride in the presence of a catalyst, such as sulfuric acid.

cellulose ether A derivative of cellulose in which one or more of the hydroxyl hydrogen's have been replaced by the alkyd groups.

cellulose ethyl plastic A plastic based on ethylene or copolymers of ethylene with other monomers, the ethylene being in greatest amount by mass. EC is characterized by toughness over a wide temperature range, dimensional stability, and freedom from odor. It is used in safety helmets, gears, slides, power housings, and particularly tool handles. Also called *ethyl cellulose plastic.*

cellulose fiberboard A generic term for a homogeneous panel made from lignocellulosic fibers, usually wood or cane, characterized by an integral bond produced by interfelting of the fibers. Other materials are added to improve certain properties. See **urea.**

cellulose lacquer See **coating, cellulose lacquer.**

cellulose nitrate plastic The first of the commercial synthetic plastics (1868) called *celluloid* discovered by J. W. Hyatt. It is a thermoplastic member of the cellulosic group made by the intimate blending of cellulose nitrate with camphor or cellulose with a mixture of nitric and sulfuric acids. Alcohol is normally employed as a volatile solvent to assist plasticization and is subsequently removed. It has toughness and ease of fabrication coupled with low water absorption, chemical resistance, and resilience. It is flammable. It was originally used in varnishes, explosives, and toilet articles. A remaining market is in table-tennis balls. Also called *celluloid, nitrate plastic,* or *celluloid.* See **camphor; Hyatt, John Wesley; powder, black.**

cellulose plastic A plastic that is based on cellulose compounds such as esters (cellulose acetate) and ethers (cellulose).

cellulose propionate plastic (CP) A plastic with properties such as CA with improvements in low temperature impact strength, weatherability, dimensional stability, and dielectric properties. See **cellulose acetate propionate plastic.**

cellulose regenerated plastic See **cellophane; cellulose sponge; fiber, rayon; viscous process; vulcanized fiber.**

cellulose sponge A sponge of regenerated cellulose that is highly absorbent, soft, and resilient when wet. It will not scratch, can be sterilized by boiling water, and is not affected by ordinary cleaning compounds.

cellulose triacetate plastic A cellulose plastic in which the cellulose is almost completely esterified by acetic acid. It is not soluble in acetone. It is used as a base for magnetic tapes and textile fibers and as a protective coating that is resistant to most solvents.

cellulosic Any of the derivatives of cellulose, such as cellulose acetate. See **plasticizer, phthalic; sheathing.**

cell unit **1.** A unit in plastic foam products. See **foam.** **2.** The basic repeating structural unit of atoms or molecules in a crystal.

Celsius The designation of the degree C on the International Practical Temperature Scale. Prior to 1948, called centigrade. The degree C is related to the degree K (Kelvin) and is used in place of K for expressing C temperature (t) defined by the equation $t = T - T_g$, where T = thermodynamic temperature and T_g = 273.15 K by definition (T_g = glass transition temperature). See **glass transition temperature; temperature.**

cement A term broadly applied to a number of adhesives as well as bonding elements. See **adhesive; bonding; calcium hydroxide; concrete.**

cement-cement See **adhesive contact cement.**

cementing See **adhesive; concrete.**

cementation **1.** With metals, a process in which steel or iron products are coated with another metal by immersing them in a powder of the second metal and heating to a temperature below the melting point of any of the metals involved. **2.** In the plastic industry, certain processes such as fluidized bed coating. See **coating, fluidized bed.**

cement adhesive See **adhesive contact cement.**

cement coated See **coating, cement.**

cement construction A process in which the outsole of a shoe is attached to the upper sole by cementing instead of sewing or by other methods. Also called the *compo process,* after Compo Industries, which introduced this method commercially into the U.S. shoe industry about 1930.

cement, contact See **adhesive contact cement.**

cementing See **adhesive, solvent.**

cement-plastic impregnated See **impregnation.**

cement, portland See **concrete.**
center gate See **mold gate, center.**
centerless grinding See **grinding, centerless.**
centerline See **drawing centerline.**
center of gravity See **gravity, center of.**
Centigrade The temperature scale on which the freezing point of water is zero and the boiling point at 100 degrees. Readings on the scale are commonly expressed as °C. Also known as *Celsius*. See **temperature.**
centrifuge A high-speed rotating apparatus designed to (1) separate solid matter from liquids or (2) separate materials of different densities. See **casting, centrifugal; coating, centrifugal atomization; coating, centrifugal or rotational; equilibrium centrifugation; mixer, centrifugal impact; rotational molding.**
centrifuge, ultra- A centrifuge capable of rotating from 20,000 to 60,000 rpm, creating forces of 250,000 times gravity. Sedimentation studies of high polymers are used for determining weight-average molecular weights and molecular weight distributions. See **atmosphere; gravity acceleration; molecular-weight centrifugation equilibrium.**
ceramic A product manufactured by the action of heat on earthy raw materials in which silicon with its oxide and complex compounds known as *silicates* occupy a predominant position. Ceramic materials contain metallic and nonmetallic elements and range from window glass to furnace brick. They are basically brittle. See **automobile, composite; composite, ceramic matrix; fiberglass; glass-ceramic; injection-molding nonplastic; mold; thermoforming heater, catalytic gas.**
ceramic precursor, plastic A plastic that is processed as an ordinary plastic to the desired shape and then pyrolyzed to ceramic to overcome the high-temperature-shaping problem. The usually extremely high softening temperature of ceramics precludes their being shaped into fibers, films, moldings, or other complex shapes through melt processing common to organic plastics. See **fiber, ceramic; injection-molding nonplastics; precursor.**
certification See **inspection; ISO-9000 certification; ISO-14000 certification; processor certification; productivity; test certification.**
C-fiber See **fiberglass type.**
C-frame machine See **clamping, tiebarless.**
C-glass See **fiberglass type.**
chain See **molecule chain length; molecule chain-length distribution; molecular chain session; polymerization, chain; polymer chain stiffening; polymer chain transfer.**
chalk See **calcium carbide.**
chalking The formation of dry, chalklike powdery residue on the surface of a material resulting from surface degradation. See **bloom; blush; defect; degradation; frosting; migration.**
chalking resistance Usually a pigmented color on plastic that resists degradation and migration.
chamfer A beveled edge or corner of a product.
change-can mixer See **mixer, change-can.**
channel black A type of filler material made by impingement of a natural gas flame against a metal plate, from which the deposit is scraped at intervals. In a high color channel black (HCC), a type of channel carbon black is of particle size about 10 mm and of the highest tinting power. See **filler; pigment.**
Chapter 11 See **legal matter: Chapter 11.**
char Carbonaceous material that is formed by pyrolysis or incomplete combustion. See **ablation; fire; flammability; incineration.**
characteristic A property of materials or products in a sample or population that, when measured, counted or otherwise observed, helps to distinguish between the materials or products.
characterizing plastic See **plastic characterization; property characterization.**
charge See **material charge.**
charge couple device See **image, charge couple device.**
charged area development See **printing, electrostatic copying charged area development.**
charge-transfer polymerization See **polymerization charge-transfer.**
charging tray See **compression molding charging tray.**
Charle's Law See **kinetic theory.**
Charpy impact test See **test, impact Charpy.**
charring See **char.**
chase See **mold chase.**
checklist See **project checklist; safety and processing.**
check ring See **screw tip, injection.**
cheese See **fiberglass, cheese.**
chelate See **chemical chelate.**
chemical **1.** Related to the science of chemistry. **2.** A substance characterized by definite molecular composition. See **polarity.** **3.** A substance obtained by a chemical process and used many different ways, including the manufacture of plastics and additives. See **computer chemometric; design, biotechnology; graphical database; plastic.**
chemical acceptor See **acceptor.**
chemical acid See **acid.**
chemical adduct A chemical compound that forms from chemical addition of two species. An example is the reaction of butadiene with styrene to form the adduct.
chemical, amphoteric Having a capacity of chemically behaving either as an acid or a base.
chemical analysis The determination of chemical structure and chemically active species. It involves both direct measurements and use of specific compounds to achieve selective reactions of a component of the substance being analyzed, to produce a readily measurable species, or to determine the reactive end product. See **polarized light; qualitative chemical analysis; spectroscopy, microwave; thermal analysis.**

chemical analysis, volumetric Analysis based on the reaction of a volume of standard solution with the material volume being analyzed.

chemical and physical characteristics Characteristics of plastics that are derived from the four factors of chemical structure, form, arrangement, and size of the polymer. For example, the types of atoms and the way in which they are joined to one another influence density. The form of the molecules and their size and disposition within the material influence its mechanical behavior. It is possible deliberately to vary the crystal state to vary the hardness or softness, toughness or brittleness, and resistance to temperature. See **atom; brittleness; chemical composition and properties of plastic; density; designing with plastic-chemical models; hardness; molecular arrangement structure; molecule; orientation and chemical property; plastic properties; polymer; Staudinger, Hermann; toughness.**

chemical assay A chemical measurement of the quantity of one or more components of material.

chemical atmospheric bond An attracting force between atoms strong enough to permit the combined aggregate to function as a unit. Different principal types of bonds recognized include covalent, ionic, metallic, and bridge.

chemical benzene ring Under normal conditions a colorless or yellowish liquid. This basic structure is an important aromatic chemical. It is an unsaturated, resonant, six-carbon ring (C_6H_6) having three double bonds. Other atoms or groups may replace one or more of the six hydrogen atoms of benzene (Bnz). It is highly toxic and flammable (autoignition point 562°C) and is used for synthesis of organic compounds. This basic structure of benzene is the most important aromatic chemical. See **aromatic; chemical chelate; phenol; radiation induced reaction.**

chemical benzene ring aryl group A group of atoms equivalent to a benzene ring or a set of fused benzene rings, less one hydrogen atom. The simplest aryl group is the phenyl group.

chemical, bicycle A substance in which only two ring structures occur. They may or may not be the same type chemical ring.

chemical blowing agent See **foam and blowing agent.**

chemical bond A link between atoms in molecules that arises from interractions between electrons. See **acetylene; atom bond, multiple; metal-adsorption calorimetry; Staudinger, Hermann; temperature and molecular bonding force.**

chemical bond cleavage The breakage of covalent chemical bonds.

chemical bond energy The energy necessary to break a chemical bond.

chemical buffer See **spectrochemical buffer.**

chemical cantenane A compound with interlocking rings that are not chemically bonded but that cannot be separated without breaking at least one valence bond. The model could resemble the links of a chain.

chemical, carbohydrate Any polyhydroxy aldehyde or ketone with the empirical formula CH_2O or substances that can be hydrolyzed to yield such compounds.

chemical chain transfer See **carbon dioxide.**

chemical change A change that occurs during processing, such as polymerization and cross-linking that increases viscosity, depolymerization or damaging of molecules that reduces viscosity, complete changes in the chemical structure that may cause color changes, and already degraded plastics that may catalyze further degradation.

chemical characterization of glass See **glass composition.**

chemical characterization of plastic A chemical composition that is basically organic polymers, which are very large molecules composed of connecting chains of carbon (C) atoms. See **chemical composition and properties of, plastic; molecular arrangement structure; molecular size; molecular weight distribution; plastic characterization.**

chemical chelate Five or six numbered ring formations that are based on intermolecular attraction of H, O, or N atoms. See **chemical benzene ring.**

chemical chelating agent A sequestering or complexing agent that, in aqueous solution, renders a metallic ion inactive through the formation of an inner ring structure with the ion.

chemical cleaning See **scouring.**

chemical cleavage The breakage of covalent chemical bonds.

chemical composition and properties of plastic The chemical structure and nature of plastics have a significant relationship not only to the properties (mechanical, physical, barrier, density, etc.) of the plastics but to the ways in which they can be processed, designed, or otherwise translated into a finished product. The majority of chemical compositions are basically organic polymers that are very large molecules composed of chains of carbon (C) items generally connected to hydrogen atoms (H) and often also oxygen (O), nitrogen (N), chlorine (Cl), fluorine (F), and sulfur (S). While polymers thus form the structural backbone of plastics, they are rarely used in pure form (neat). In almost all plastics other useful and important ingredients are added to modify and optimize their properties for each desired process and application; additives effect both processability and product performance. See **additive; barrier via chemical modification; carbon; chemical and physical characteristics; copolymer; designing with plastic tailor-made models; design theory and strength of material; molecular basic property effect on product; molecular bonding; monomer; organic; petrochemical; plastic, neat; plastic properties; polymer evolution; rheological mechanical spectrometer; Staudinger, Hermann; strength of material.**

chemical compound A substance composed of atoms of two or more elements chemically united in a fixed proportion. See **atom; compound; molar mass of a chemical compound.**

chemical configuration **1.** The chemical structure that is produced by the cleavage and reforming of covalent bonds; the arrangement of polymers along a plastic molecule chain. **2.** The structural makeup of a chemical compound, especially with reference to the spatial relationship of the constituent atoms.

chemical conjugate The regular alternation of single or double bonds between atoms of a molecule.

chemical coupling agent See **fiberglass binder/sizing coupling agent.**

chemical decomposition See **chemical reclamation.**

chemical degradation See **degradation, swelling, extraction, and random.**

chemical dehydrogenation A chemical action designed to remove hydrogen from a substance. See **hydrogenation.**

chemical distillation It is an important process widely used in chemistry, in which liquid or liquified materials are separated by evaporation and recondensation. See **distillation.**

chemical domain A morphological term used in noncrystalline systems, such as block copolymers, in which the chemically different sections of the chain separate, generating two or more amorphous phases.

chemical element See **element.**

chemical environment See **zirconium.**

chemical enzyme See **catalyst, enzyme.**

chemical etching The exposure of certain plastic surfaces to a solution of reactive chemical compounds. Solutions are oxidizing chemicals, such as sulfuric and chromic acids, or metallic sodium in naphthalene and tetrahydydrofuran solution. Such solutions are highly corrosive and require special handling and disposal procedures. This treatment causes a chemical surface change, such as oxidation, thereby improving surface wettability and increasing its critical surface tension. It may also remove some material, introducing a microroughness to the surface. Chemical etching requires immersion of the part into a bath for a period of time, rinsing, and drying. Because this process is more expensive than most other surface treatments, such as flame treatment, it is used when other methods are not sufficiently effective. Fluoroplastics are often etched chemically because they do not respond to other treatments; acrylonitrile-butadiene-styrenes are usually etched for metallic plating; and so on. See **chemical milling; chemical surface treatment, plastic; chromic acid etching; decorating pretreatment; etching; flame treating; machining; photoetching tool steel; surface treatment.**

chemical etching activation The chemical etching process of making a surface more receptive to bonding with a coating, encapsulation, and so on.

chemical extraction See **degradation, swelling, extraction, and random.**

chemical, fluoro- An organic compound, not necessarily hydrocarbons (usual plastics), in which a large percentage of the hydrogen directly attached to carbon has been replaced by fluorine. See **fluoroplastic; polychlorofluorocarbon.**

chemical foamed plastic See **foam.**

chemical formula An expression showing the chemical composition of a compound using a combination of symbols for the component elements. See **formula, empirical; valence.**

chemical hole burning See **photochemical hole-burning spectroscopy.**

chemical, hydroxy group Chemical group of OH (oxygen-hydrogen) compounds (methyl alcohol, methanol, or carbinoll).

chemical, hydroxyl group Chemical group (OH) consisting of one hydrogen atom bonded to one oxygen atom.

chemical information See **computer batch processing.**

chemical inhibitor See **inhibitor.**

chemical intermediate A chemical obtained as a midstep in the manufacture of another chemical. See **antimony oxide.**

chemical introfier A chemical that converts a colloidal solution into a molecular one. See **impregnation, introfaction.**

chemical marine sediment analysis See **bottle standard marine reference material.**

chemical microbe See **biodegrading microorganisms.**

chemical milling A controlled etching process that depends on the etching action of an acid or alkali that uniformly attacks all exposed areas of the product. A mask or protective coating is used on those surfaces that are not to be etched. Also called *chemical blanking* or *chemical machining*. See **chemical etching; machining.**

chemical mixing tank See **ice, dry.**

chemical modeling See **computer-aided molecular graphic.**

chemical modification of plastic See **barrier via chemical modification.**

chemical nomenclature See **organic acid.**

chemical octet rule The principle that an atom other than hydrogen tends to form bonds until it is surrounded by eight valence electrons.

chemical, petro- See **petrochemicals.**

chemical polymer In chemistry, a polymer is described by drawing its physical structure of atoms. An example is polyethylene with its hydrogen (H) and carbon (C) atoms bonds. The bonds on the carbon atoms indicate that molecules can form bonds with like molecules to form a polymer chain. Many polymers can be made from the same carbon-atom backbone by substituting another element or chemical compound for one or more of the H atoms. Polymer molecules are distinguished from other chemical compositions primarily by their tremendous size; most of their properties result from this unusual size. Many of the properties and applications of plastics are greatly influenced by the individual atoms and functional groups within the polymer molecule. See **atom; chemical composition and plastic properties; chemistry; design, biotechnology; molecule; plastic, neat; polymer chemistry terminology.**

chemical property See **test, chemical property.**

chemical pulping See **wood pulping.**

chemical pump See **design chemical processing pump.**

chemical, pure See **reinforcement, whisker.**

chemical rate law See **rate law.**

chemical reactant A starting substance that is used in a chemical reaction. See **reaction quotient.**

chemical reaction A chemical change in which two or more atoms or molecules create a new substance. See **adiabatic calorimeter; catalyst; enthalpy of reaction; material, powder; molecularity; phase change.**

chemical reaction, acid A chemical reaction that is produced by an acid. See **acid; hydrochloric acid.**

chemical reaction, addition A type of reaction of unsaturated hydrocarbons with hydrogen, halogens, halogen acids, and other reagents, so that no change in valence is observed and the organic compound forms a more complex one.

chemical reaction aeration See **aeration.**

chemical reaction, autoclave See **autoclave.**

chemical reaction, catalyst See **catalyst.**

chemical reaction, chain A chemical or atomic reaction in which the products of the reaction initiate a further reaction, and so on.

chemical reaction, chlorination See **carbon tetrachloride.**

chemical reaction, condensation One of a class of chemical reactions involving a combination between molecules or between parts of the same molecule. See **condensation; polymerization, condensation.**

chemical reaction, cryochemistry See **chemistry, cryo-.**

chemical reaction, electro- See **electrochemical reaction.**

chemical reaction, elementary step A reaction that occurs on the molecular level exactly as "written." An overall reaction may involve one or several elementary steps.

chemical-reaction energy See **energy, van Hoff isotherm.**

chemical reaction, engineering See **exotherm; reactor technology.**

chemical-reaction equation A chemical equation in which only those species that actually take part in the reaction are shown.

chemical-reaction equivalence point The point at which the reaction in a titration is complete.

chemical reaction, exothermic See **exothermic reaction.**

chemical reaction, first-order A reaction whose rate depends on the reactant concentrations raised to the first power.

chemical reaction, Gatterman The reaction of a phenol or phenol ester and hydrogen cyanide, in the presence of a metallic chloride such as aluminum chloride to form, after hydrolysis, an aldehyde. See **aldehyde.**

chemical reaction, half The oxidation or reduction part of a redox reaction. The equation for a reduction half-reaction shows electrons on the left-hand side. An oxidation half-reaction shows electrons on the right-hand side. The sum of the two such half-reactions gives the overall redox reaction. See **redox.**

chemical reaction, half-cell The reaction at the electrode in an electrolytic or galvanic cell. See **electrolysis.**

chemical reaction, half-life The time required for one-half of a given material to undergo a chemical reaction.

chemical reaction heat loss See **adiabatic calorimeter; calorimeter.**

chemical reaction, induced See **radiation-induced reaction.**

chemical reaction, polymerization See **alkali metals and derivatives.**

chemical reaction, productive See **reactor, vapor-phase.**

chemical reaction, valence electron. An electron that is gained, lost, or shared in a chemical reaction. See **valence band.**

chemical reaction versus temperature rate The rate of chemical reaction versus temperature is shown in an arrhenius equation.

chemical reaction, Zimmermann The reaction that occurs between methylene ketones and aromatic polynitro compounds in the presence of alkali. See **ketone.**

chemical reactor, extruder See **extruder, reactive processing.**

chemical reclamation With chemical reclamation, plastics are decomposed by physiochemical processes that take them back to their basic building blocks. Gaseous or liquid hydrocarbon compounds are thereby reclaimed. Processes that are being used include hydration of plastic wastes, hydrolysis (alcoholysis, glycolysis), and pyrolysis. See **hydrolysis; plastic and pollution; recycling, chemical; recycling method, economic evaluation of; waste.**

chemical recycling See **recycling, chemical.**

chemical resistance The ability of a plastics to withstand attack of acids, alkalis, solvents, and other chemicals. Generally plastics have good chemical resistance. See **energy reclamation.**

chemical safety and processing Some of the products developed by the chemical and plastic industries involve a certain acceptable risk. The handling of these products must be made hazard-free for people and the environment. See **risk, acceptable; safety and processing.**

chemical saturation The absence of double or triple bonds in a chain organic molecule such as that of some polymers, usually between carbon atoms. Saturation makes the molecule less reactive and polymers less susceptible to degradation and cross-linking. See **saturation.**
chemical spray plating See **plating, silver spray.**
chemical structure See **chemical composition and plastic properties; designing with plastic-chemical models; molecular structure configuration; rheological mechanical spectrometer.**
chemical structure and mechanical properties See **rheological mechanical spectrometer.**
chemical structure building block See **Staudinger, Hermann.**
chemical structure, discrete A chemical structural element that is distinct or not connected.
chemical structure modeling See **designing with plastic-chemical models.**
chemical structure, understanding See **Staudinger, Hermann.**
chemical surface treatment, plastic A method of rendering inert plastic receptive to inks, adhesives, and paints. Techniques include chemical etching, flame treatment, and abraiding surface. See **abraid; chemical etching; fluorination; gasoline tank permeability; sulfonation; surface CASING; surface treatment.**
chemical synonym data-case A chemical source for identification that includes formulas, codes, common names, and official names for chemicals.
chemical synthesis The creation of a substance that either duplicates a natural product (material) or is a unique material not found in nature. This occurs by one or more chemical reactions. Though syntheses are more readily achieved with organic compounds because of the great versatility of the carbon atom, extremely important syntheses of other atoms also exist such as inorganic silicones. Basically it is the building of chemical compounds (polymers, etc.) from their elements or from simpler compounds. See **element; packing; polarity; synthetic.**
chemical test See **test, chemical.**
chemical theory polymer See **Staudinger, Hermann.**
chemical treatment See **chemical surface treatment, plastic.**
chemical unsaturation The presence of double or triple bonds in a chain organic molecule such that some are polymers, usually between carbon atoms. Unsaturation makes the molecule more reactive, especially in free-radical addition reactions such as addition polymerization, and polymers more susceptible to degradation, cross-linking, and chemical modification.
chemical valence See **valence.**
chemical vapor deposition (CVD) A process that produces high-performance reinforcing filaments for use in reinforced plastics. It is a process in which desired reinforcement material is deposited from vapor phase onto a continuous core; boron on tungsten and silicon carbide on carbon filament substrates are examples. Fine-grained filaments are formed at one-third or less of the melting point of the material for simple crystal structures and somewhat higher for more complex crystal structures. Typically, a filament is run through a chamber where the filament is subjected to electrical resistance heating, and surface gases decompose on the heated substrate. See **fiber, boron; fiber, silicon carbide; reinforcement; xylylene plastic.**
chemical writing See **technical writing.**
chemisorption Adsorption, especially when reversible, by means of chemical forces in contrast to physical forces. See **adsorption.**
chemistry A science that deals with the composition, structure, and properties of substances and of the transformations that they undergo. It has contributed to our understanding of the mechanism of the reactions of carbon compounds. Its value and importance continue to permit an endless growth of new plastics with improved performances. See **chemical composition and plastic properties; chemical polymer; design, biotechnology; interpenetrating network; plastic raw material to product; rheological mechanical spectrometer; strengthening plastic mechanism.**
chemistry, acetylene In synthesizing calcium carbide from lime and coal in a furnace at 2,000°C, carbide reacts vigorously with water to produce an unsaturated hydrocarbon acetylene (ethine) and calcium hydroxide. This reaction is the basis for the so-called acetylene chemistry. See **acetylene; calcium hydroxide.**
chemistry, analytical The subdivision of chemistry that is concerned with identification of materials (qualitative analysis) and with determination of the percentage composition of the mixtures or constituents of a pure compound (quantitative analysis). The gravimetric and volumetric (or wet) methods such as precipitation, titration, and solvent extraction are still used for routine work; newer titration methods are available. Among these are infrared, ultraviolet, x-ray spectroscopy, and chromatography of various types. Optical and electron microscopy mass spectrometry, microanalysis, nuclear magnetic resonance, and others fall within the area of analytical chemistry. See **infrared spectroscopy; spectroscopy, nuclear magnetic resonance; thermal analysis.**
chemistry, bio- Originally a subdivision of chemistry but now an independent science. It includes all aspects of chemistry that apply to living organisms. See **body; design, biotechnology; hemocompatibility.**
chemistry, conjugated In chemistry, the regular alteration of single and double bonds between atoms of the molecules.
chemistry, cryo- The branch of chemistry that is devoted to the study of reactions occurring at extremely low temperatures of −200°C (−328°F) and lower. See **chemical reaction; cryogenic.**
chemistry, electro- The branch of science and tech-

nology that deals with transformations between chemical and electrical energy.

chemistry, inorganic A major branch of chemistry that embraces all substances except hydrocarbons and their derivatives, or all substances that are not compounds of carbon dioxides and carbon disulfides. See **plastic, inorganic.**

chemistry, organic The study of the compositions, reactions, and properties of carbon-chain or carbon-ring compounds or mixtures that are prepared. See **carbon; chemistry, inorganic; organic.**

chemistry, photo- See **photochemistry.**

chemistry, polymer See **chemical polymer; chemical structure; design biotechnology; polymer chemistry terminology.**

chemistry, radio- See **radioactive decontamination.**

chemistry, stereo- The branch of chemistry dealing with the spatial arrangement of atoms or groups of atoms that make up molecules. Stereoisomerism is possible in the polymerization of nonsubstituted ethylenes. Two ordered or stereoregular polymers are possible, isotactic and syndiotactic, wherein the substituent R groups on successive chiral carbons in the polymer chain have the same and opposite relative configurations, respectively. See **molecular structure, isotactic; isotactic plastic.**

chemistry terminology See **polymer chemistry terminology.**

chemistry, thermo- The branch of thermodynamic that deals with the evolution or absorption of energy as heat in chemical processes. Thermodynamic is that part of chemistry that deals with the energy change involved in chemical reactions and changes the physical state of the substance. It basically is the measurement, interpretation, and analysis of heat changes accompanying chemical reactions and changes in state. See **energy absorption; thermodynamic.**

chemometric See **computer chemometric.**

chewing gum See **chicle.**

chicken-skin See **orange peel.**

chicken test See **test, aircraft canopy.**

chicle A natural thermoplastic, gumlike material obtained from the latex of the sapodilla tree native to Mexico and Central America. It softens at 32°C (90°F), is insoluble in water, and is soluble in most organic solvents. Its major use is in chewing gum after adding sugar and specific flavoring. See **plastic, natural.**

chill **1.** The cooling action by water, air, and other mediums during processing. A mold is cooled by circulating water or water-ethylene glycol through it. See **coolant.** A plasticator barrel is cooled with air or water. See **plasticator.** **2.** An object, usually metal, imbedded in a portion of a part or mold to accelerate the local rate of heat removal from the plastic being processed. See **mold heat-transfer device.** **3.** Chill rolls are used to produce film, sheet, and coatings. See **extruder roll, cooling.** **4.** To refine a graphite structure or cause formation of primary carbides. See **graphite.**

chiller A device, that cools materials at preset processing temperature. There are portable (beside the machine) and central types. Each has advantages and disadvantages. The type used depends on the cooling temperature capacity requirement, length of run for the same part, type of materials processed, and space available. For most operations equipment is either at 80 to 85°F (27 to 30°C) or 20 to 50°F (−7 to 10°C). Mechanical refrigeration is required to produce chilled water in the lower temperature ranges. Also called *temperature controller.* See **coolant; temperature controller; water, magnetic.**

chime See **container chime.**

china, bone See **bone china.**

china clay Hydrated aluminum silicate, used as a filler. It is a mineral aggregate consisting chiefly of microcline, albite, and/or anorthite and derived from the weathering of the aluminous mineral feldspar. This refractory clay is fired to a white or nearly white color. See **filler, mineral; kaolin.**

chinese white. A term used in the paint industry for zinc oxide and kaolin used as a white pigment. Also called *zinc white.* See **paint.**

chip See **integrated circuit, plastic.**

Chisolm's Law See **problem and solution.**

chlorinated compound solvent A solvent that confers low-flammability properties in comparison with other types of solvents. It is used where fire hazards are a matter of importance. See **fire; solvent.**

chlorinated diphenyl A series of plasticizers ranging from mobile oily to hard plastics. They are nonoxidizing and noncorrosive, and various grades are available. They are used with chlorinated rubber, polystyrene, and polyvinylidene chloride.

chlorinated flame retardant See **phosphorous-base flame retardant.**

chlorinated hydrocarbon An organic compound that has chlorine atoms in its chemical structure. It is one of a series of secondary plasticizers used in vinyl compounds, plastisols, and organosols. See **polyether chlorinated plastic; polyethylene plastic, chlorinated; polyvinyl chloride plastic, chlorinated.**

chlorinated solvent A group that is different from hydrocarbon solvents. They dissolve oil and fat and are not ordinarily dissolved by aromatics. Common types are carbon tetrachloride, methylene chloride, ethylene chloride, and trichloro-ethylene.

chlorine (Cl) A heavy, greenish-yellow poisonous gas, or clear amber liquid, derived mainly from the electrolysis of brine. A powerful oxidizing agent, it is widely used in the manufacture of many important chemicals such as ethylene glycol and trichloroethylene and is also used in the production of vinyl chloride and vinylidene chloride. See **oxidizing agent.**

chlorobutyl rubber See **polyisobutylene butyl rubber.**

chlorofluorocarbon plastic A plastic that is made from monomers composed of chlorine, fluorine, hydrogen, and carbon only. It provides improved performances that range from chemical to heat resistance. See **polychlorofluorocarbon.**

chloroprene plastic A plastic that is used to form materials resembling rubber. See **neoprene elastomer; polychloroprene elastomer.**

chlorosulfonated polyethylene plastic See **polyethylene plastic, polychlorosulfonated.**

chlorotrifluoroethylene See **polychlorotrifluoroethylene plastic.**

choker bar See **die restrictor bar.**

chopped fiber See **fiberglass, chopped.**

Christmas decoration See **blow molding, extruder blow-action.**

chromatic aberration In resinograph, a defect in a lens or lens system resulting in different focal lengths of different wavelengths. An image produced by such a lens shows color fringes around the border of the image. See **lens; apochromatic resinograph.**

chromatic color See **colorant; saturation.**

chromatography A technique for separating a sample material into constituent components and then measuring or identifying the compounds by other methods. For example, separation, especially of closely related compounds, is caused by allowing a solution or mixture to seep through an absorbent such as clay, gel, or paper, and each compound becomes adsorbed in a separate, often colored layer. See **alumina, activated; chemistry, analytical; resinography; spectroscopic analysis; thermal analysis.**

chromatography, gas (GC) A method of separating, characterizing, and quantifying the vaporized components of samples using both conventional and pyrolysis techniques. Use includes identification of plastics and elastomers by GC fingerprinting, compositional analysis of copolymers and blends, and determination of residual monomers and highly evaporative agents. See **vapor detector, dielectric.**

chromatography, gel (GC) A method of assessing the composition and characteristics of a plastic compound by separating its components on the basis of molecular size (molecular weight). Since the weights of the organic molecules in a material vary from a few thousand to a few million, the polymers, oligomers, monomers, or additives component can be readily separated by size. The process requires that the sample be in liquid form or be dissolvable. It is used with virtually all thermoplastics and the unreacted B-stage thermoset plastics (prepregs, etc.). See **polyacrylamide plastic; thermal analysis.**

chromatography, gel permeation (GPC) A form of liquid chromatography in which the polymers are separated by their ability or inability to penetrate the material in the separation column. It is used to determine molecular weight distribution of a polymer by this fractionation technique. The effective size of a molecule in solution is related closely to the molecular weight. See **analytical instrument; molecular weight distribution.**

chromatography, ion (IC) A method of utilizing the principles of ion exchange to separate mixtures of ionizable materials and, in most cases, a conductivity detector to sense the components resolved. A liquid sample is introduced at the head of an appropriate separator column into a stream of ionic eluant, which then carries the mixture through the column and toward a detector. The time at which a component exits the column is a clue to its identity, whereas the size of the peak is related to concentration.

chromatography, liquid A technique of separating components of a mixture by differences in their rate of elusion arising from interactions between the sample and the column-packing material.

chromatography, thin layer (TLC) A microtype of chromatography in which a thin layer of special absorbent is applied to a glass plate, a drop of solution of the material being investigated is applied to its edge, and that side of the plate is then dropped into an appropriate solvent. The solvent travels up the thin layer of the absorbent, which selectively separates the molecules present in the material.

chrome plating An electrolytic process that deposits a hard, semigray film of chromium metal onto the properly prepared surfaces of plastic parts. It is used for EMI/RFI shielding, corrosion resistant metal coating, and plastic part coating. See **electromagnetic interference; plating.** This electrolytic process causes chromium to be deposited onto the surfaces of other metals. Chrome-plated surfaces are frequently used where resistance to corrosion or abrasion is needed such as molds, dies, and rolls. See **die coating; mold-cavity surface; screw coating.** It is available and mined in the former USSR, South Africa, Zimbabwe, Philippines, Turkey, and Cuba. Also called *chromium plating* or *Cr plating.*

chromic acid etching In adhesive bonding, a surface chemical treatment in which chromic acid introduces oxygenated reactive molecular groups to the part surface and to form rootlike cavities as sites for mechanical interlocking. Commonly used for polyolefins, acrylonitrile-butadiene-styrene, polyphenylene oxide, and polyoxymethylene. See **adhesive bite; chemical etching; surface treatment.**

chromium plating See **chrome plating.**

chromophore molecule See **molecule, chromophore.**

chronotherapeutic See **medical chronotherapeutic.**

chrysotile See **asbestos.**

chuck See **extruder roll-winding chuck.**

cine-radiography See **radiography, cine-.**

circuit An electrical circuit pattern. See **electric; filament-winding circuit; injection-molding circuit board; printed circuit board.**

circular area See **area, circular mil.**

circumferential winding See **filament winding, circumferential.**

circumstantial evidence See **legal matter: circumstantial evidence.**

citrate plasticizer A main group of plasticizers that find an outlet in the production of low-toxicity products. See **plasticizer.**

civil justice See **legal matter: forensic science and plastic; legal matter: plaintiff.**

civil work See **geomembrane; geotextile.**

clad Surface sheathed.

cladding A plastic coating on different materials such as plastics, metals, and aluminum. Its purpose is to improve specific properties of the substrate. Property improvements obtained, such as abrasive and corrosion resistance, and color, depend on the plastic used and method of processing. See **coating; surface.**

clamping A device or system that provides pressure to molds and dies, such as injection molding, blow molding, compression molding, and reaction injection molding. For example, in the injection-molding machine, the clamping unit is that portion in which the mold is mounted. It provides an accurate and controlled motion and force to close and open the mold and to hold the mold closed during plastic injection. When the clamp is closed in a horizontal direction (the most popular), the clamp is referred to as a horizontal clamping system. When in the vertical, it is a vertical clamping system. See **injection-molding machine; mold; press.**

clamping area The largest rated molding area that the machine can hold closed under full molding pressure.

clamping, book-type See **clamping platen, book-opening.**

clamping, close low pressure A provision in the machine to lower the clamp closing force to minimize the danger of mold damage caused by molded parts caught between the mold halves.

clamping close-position ejector mechanism A provision in the machine-control circuit to allow a clamp to fully open and then close to a predetermined position. It is generally used to allow the mold-ejector (knockout) mechanism to retract so inserts can be placed in the mold. See **mold ejector.**

clamping daylight opening The clearance between two platens of a press (blow molding, compression molding etc.). It provides space for the mold height plus the space needed after the mold opens and the part has to be removed from the mold cavity. There is a maximum and minimum daylight open distance. See **injection-molding machine daylight.**

clamping, electrical Two-platen or three-platen systems that use electrical motor drive systems and provide advantages such as reduced power consumption during use, clean-room operation, and reduced floor space. See **clamping, hydraulic.**

clamping, hybrid force See **hybrid.**

clamping, hydraulic A clamp system that uses a large hydraulic cylinder and piston to directly develop clamp force. There are different arrangements used such as the usual three-platen, two-platen, C-clamp machines, rotating platen, and tiebarless machines with each providing different benefits. As an example, the two-platen system is much shorter, requires less floor space (20 to 40%), and weighs less than a three-platen hydraulic or toggle system. A two-platen typically features a drive mechanism that pulls rather than pushes the moving platen. See **clamping, electrical; platen, press.**

clamping, hydroelectric A system that uses a combination of hydraulic and electrical systems to take advantage of their benefits.

clamping, hydromechanical A system that partly uses a mechanical system, such as toggle system, and partly a hydraulic system to increase speed of operations, reduce operating costs, and so on.

clamping, magnetic A system that has direct mounting of cavity inserts in pockets in the platens. Platens are brought together with clamping force achieved by mutual magnetic attraction.

clamping mold, slow breakaway A provision designed to provide slow platen movement for an adjustable distance during the initial opening of the mold that may be required for molding certain plastics or shapes.

clamping, open-stroke interruption A complete stop of the clamp opening stroke to allow an auxiliary operation before completion of the opening stroke.

clamping platen A mounting plate, usually two platens, of a press (injection molding, compression molding, etc.) to which the mold assembly is bolted or attached mechanically. See **platen; press.**

clamping platen, book-opening The conventional way for a press to open is having the two platens remain parallel from open-to-close-to-open. Like the way a textbook opens from its one side, these presses use that type of motion with the platens. It is used in different processes such as compression molding, reaction injection molding, and printing. It has been popular since at least the 1930s when it started in rubber compression molding. Also called *tilting press.* See **compression molding; printing; reaction injection molding.**

clamping platen, floating The movable platen between the stationary and normal moveable platens resulting in two or more daylight openings where two or more molds can be used simultaneously during one machine operating cycle. See **mold, stack.**

clamping platen, movable The platen to which half of the mold is secured and moves to close and open/separate the mold halves. See **mold half.**

clamping platen, parallelism and flatness in The ability of a molding press during use to maintain the platen surfaces parallel to each other and their surfaces remaining flat (no bellowing, etc.).

clamping platen, rotary A technique that is used to overmold two or more materials into a single part for different processes (injection molding, compression molding, foaming, etc.). For each plastic, a separate injection, extruder, or other feed unit is required. Two or more mold halves are arranged in a circle on the moving platen with the matching mold halves attached to the fixed platen. Basically the process starts with the first closed mold cavity receiving a plastic. On opening, that cavity with the partially solidified plastic is rotated into the next position where its matching mold cavity is recessed to receive the next shot. With three or more plastics, this molding procedure continues. When the platens close after the initial start-up, each cavity is simultaneously injected with the required plastic. Also called a *carousal system* when platens operated horizontally or *ferris wheel* when operating vertically. See **blow molding, extruder (continuous operation); injection molding, two-shot; molding, rotary; rotational molding type.**

clamping platen, shuttle Molds in which usually two or more shuttles are moved so that one mold is positioned to receive plastic material and then moves to permit another mold to receive, with this cycle repeating. The result is to permit insert molding and reduce the molding cycle. See **blow molding, extruder (continuous operation).**

clamping platen, stationary The fixed platen on which the stationary half of the mold is fastened. This member usually includes a mold-mounting pattern of bolt holes or T slots; a standard pattern is recommended by Society of the Plastics Industry. For certain processes, such as injection molding, a mold with a sprue is properly aligned with the platen's opening and is secured to this platen so that the injection-molding machine nozzle can be firmly fitted. This platen, with the nozzle leaning against the mold's sprue, does not move or separate under normal operation.

clamping platen troubleshooting Problem solving when platens do not operate properly or the molding operation is not properly controlled. Typical problems that can develop include mold wear or damage, mold flashing, out-of-tolerance parts, tiebar stress, and unbalanced mold filling. In addition to various textbooks, material suppliers and machine manufacturers generally provide guidelines relating these type problems with causes and solutions. See **troubleshooting.**

clamping preclose Closing the mold to some point near the closed position before and after final closing. This permits bumping, improved parison pinch areas for blow molding, and mold safety measures. See **blow molding, extruder parison.**

clamping press See **press.**

clamping pressure The force in tons (T) that is exerted to hold the two platens or mold halves together when (1) laminating, (2) melt under pressure fills the mold cavity, or (3) air pressure pushes the melt parison against the mold cavity (during blow molding). Also called *clamping force* and *locking force.* See **pressure.**

clamping pressure, injection molding machine Depending on what plastic is being molded, the IMM clamping force may be from less than 20 to over thousands of tons. Different plastics require different pressures applied on their melt in the mold cavity, which can range from 2,000 to 30,000 psi (14 to 207 MPa). The average machine uses a range from 100 to 400 tons, and large machines provide thousands of tons of clamping pressure. A force is also required to open the mold that is usually much less than the clamping force. So one has to ensure that opening clamping pressure is available. Usually this requirement is not a problem. Clamping predominantly uses hydraulic systems. Also becoming popular are all electric-drive systems and hydraulic/electrical hybrid systems. The actual mechanical mechanisms range from toggle to straight ram systems. Each of these different systems has its individual advantages. See **clamping, electrical; clamping, hydraulic.**

clamping pressure measured Methods of pressure measurement includes (1) pressure transducer between closed platens, (2) sum of the tie bar forces, (3) force in a toggle mechanism, and (4) oil pressure in a hydraulic system or electric power that uses electric drive system. Measurements usually are made by some type of electrical strain gauge in the tie bars and offer the advantage of monitoring the forces in the individual bars. Thus, uneven loads or even overloading of individual bars caused by unbalanced or worn molds, and other problems, can be identified quickly to avoid major problems. Also called *clamping pressure* and *locking force.* See **clamping tiebar sensing; pressure-detecting film.**

clamping, rotary See **clamping platen, rotary; press, rotary.**

clamping shut height The minimum distance between machine platens when the clamp is closed.

clamping, shuttle See **clamping platen, shuttle.**

clamping stroke maximum The maximum distance that the opening and closing mechanism can traverse a platen. This action can be adjusted to shorten the travel to meet mold or molding requirements.

clamping tie bar A bar (rod) between the fixed platen on which the moving platen slides. It serves as a tension member of the clamp when the mold is closed.

clamping tiebar dimension The distance between tie rods (bars) through which the mold must fit.

clamping, tiebarless Without the tie bars, larger molds can reduce injection-molding machine cost, mount larger molds in a smaller IMM, permit easier mold mounting, and allow simpler part-handling automation. Tiebarless design is of a "C" frame construction to provide clamping pressure and proper parallel as well as operating platens; does not use standard 3 or 4 tie bar layouts.

clamping tie-bar, retractable A device that is used to unlock a tie bar. It permits the installation of molds that would occupy the complete platen minus the tie rod areas. Thus the mold literally has holes.

clamping tie-bar sensing Using sensors, such as electrical strain gauges, to detect the stretch or load applied and if an unbalance situation occurs, to alert the operator with an indicator. During clamping and applying pressure on the molds, the tie rods stretch. If everything is in balance, the platens and mold stretch evenly. The distance the rods stretch is directly proportional to the applied load. Bar sensing can also be used to signal the switch from pack to hold pressure, a potential alternate or support for a pressure transducer.

clamping, toggle action A machine clamping system that uses a toggle mechanism to develop clamp force by stretching the tie rods attached to the movable platen.
clamshell foamed See **environment and public opinion.**
clamshell package See **thermoforming, clamshell.**
clarifier See **additive clarifier; adhesive, isinglass.**
clarity See **medical-device packaging clarity; transparent.**
Clash-Berg test See **test, stiffness, Clash-Berg.**
clasp See **packaging clasp.**
classification See **ISO; Underwriters Laboratory classification; test and classification.**
clay, ball A secondary clay that has good plasticity, strong bonding power, high temperature processing, high dry strength, and processes to a white or creamy colored product. It is used as a bonding and plasticizing agent. An example is PVC floor and wall tiles.
clay filler A natural-occurring sediment that is rich in hydrated silicates of aluminum predominating in particles of colloidal or near colloidal size. It is used extensively as a filler in plastics. See **china clay; fuller's earth; kaolin; steatite.**
clay, hard Sedimentary rock that is composed mainly of fine clay mineral material without natural plasticity; any compacted clay.
clean-area fabricating A milieu of artificial purity that protects sensitive products from air-laden particle contamination. Required measures include (1) a workplace correctly designed for clean-air technology and suitable conduct by employees, (2) effective filtration of the air supply and carefully planned air ducting, (3) easy-to-clean surfaces throughout the clean-area, (4) a high degree of automation of all work operations, and (5) regular monitoring with the aid of suitable particle-measuring technology. See **fabricating; maintenance; troubleshooting.**
cleaning A technique that is used to clean fabricated products. Techniques include solvent, ultrasonic, blasting with dry ice (carbon dioxide) pellets, toxic chemicals, and even PCFC-based solvents, particularly for medical devices. See **polychlorofluorocarbon; scouring.** Cleaning is done on a periodical maintenance time schedule to ensure the proper operation of equipment. Available are cleaning devices for molds, extruder dies and screen changers, molded flash, and so on that operate economically and safely remove contaminated plastics. The routine techniques used include blow torches, hot plates, hand working, scraping, burn-off ovens, vacuum pyrolysis, hot sand, molten salt, dry crystals, high-pressure water, ultrasonic chemical baths, heated oil, and lasers. Personnel have to be careful not to damage expensive tooling by spot annealing or mechanical abuse. Commercial cleaning systems include aluminum oxide beds (fluidized beds), salt baths, hot air ovens, and vacuum pyrolysis. For example, the vacuum pyrolysis cleaner utilizes heat and vacuum to remove the plastic. Most of the plastic is melted and trapped. The remaining plastic is vaporized and appropriately collected in a trap. See **aerated sand cleaning, hot; carbon dioxide; coating, fluidized-bed metal stripping; decorating preparation problem; extruder screw pulling; injection-molding screw pulling; latex; mold cleaning; scouring; screw removal; sterilization; stripping fork.**
cleaning, abrasion A cleaning method that removes surface contamination and increases surface roughness. Removal of surface contamination eliminates a potential existing weak boundary layer. It has a positive effect on laminating or adhesion. Cleaning is usually carried out by several mechanical processes such as dry blasting with nonmetallic grit (flint, silica, aluminum oxide, plastic, walnut shells), wet abrasive blast (slurry of aluminum oxide), hand or machine sanding, or scouring with tap water and scouring powder. See **abrasive; mold-cavity grit blasting; surface treatment.**
cleaning, chemical See **scouring.**
cleaning, dry ice See **carbon dioxide.**
cleaning, hot salt A cleaning method using molten salt in a container. It is a very old cleaning method for metal molds and dies. Cleaning cycles are as short as one minute, depending on tool shape and plastic. See **salt bath.**
cleaning, metal part See **aerated sand cleaning, hot.**
cleaning, screw See **extruder screw pulling; injection-molding screw pulling; stripping fork.**
cleaning, self- See **reaction injection-molding self-cleaning.**
cleaning, solvent A method of cleaning that may consist of wiping, immersion in a solvent, spraying, or vapor degreasing. Wiping is the less effective process and may result in distributing contaminate over the surface rather than removing it. Immersion, especially if accompanied by mechanical or ultrasonic scrubbing, is a better process. It is even more effective if followed by either immersion or a spray rinse. Vapor degreasing is by solvent vapors condensing on parts; it is the most effective process because the surfaces do not come in contact with the contaminated solvent bath. Vapor degreasing is carried out in a tank with a solvent reservoir on the bottom. The solvent is heated, and vapor condenses on the cool plastic surfaces. The condensate dissolves surface impurities and carries them away. Cleaning action is as fast as a minute. See **aldehyde; solvent; surface treatment.**
cleaning, ultrasonic A cleaning method that is used for thoroughly cleaning plastic parts, particularly electrical and mechanical parts. A transducer mounted on the side or bottom of a cleaning tank is excited by a frequency generator to produce high-frequency vibrations in the cleaning medium. These vibrations dislodge contaminates from crevices and blind holes that normal cleaning methods would not affect.
cleaning, vacuum-pyrolysis A method of cleaning metal parts in pyrolytic ovens. Instead of sealing the chamber and starving oxygen, as burn-off ovens do, pyrolytic ovens pull a vacuum over parts to remove combustible air.

Theoretically, a vacuum oven is the safest method, since it removes all oxygen from the heating chamber. See **pyrolysis.**

cleanroom A low-particle-count production room. In the past cleanrooms were found in a few large plants or specialized operations concerned with medical or pharmaceutical products. The trend toward cleanroom production has been extended to achieve the necessary quality levels from the electronics and microelectronics industries and lately even from the automotive and entertainment industries. With careful planning, considerable savings can be made in investments and operating costs. The required degree of cleanliness, in particular, determines costs to a large extent and is directly influenced by a number of factors such as the size of the room and contaminants. The worst enemy is dust, which must be eliminated. The greatest dust producer is human beings. The smallest dust particles are less than 0.5 μm. Moreover, the number of particles depends on the type and speed of any motions. Since the continued production of dust is unavoidable, measures must be taken to reduce the total particle count. The lower the permissible amount of dust in a planned production area, the greater the resultant costs. See **design, medical-device; quality control; test.**

cleanroom standard The U.S. Federal Standard 209E, Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones, must be met by manufacturers who want to conform to quality-system regulation. Via the industrial International Standardization Organization European Community, it has been integrated with ISO. Among the more important recent changes are metrication, revision of the upper confidence level requirement, provisions for sequential sampling, and an alternative verification procedure based on determination of the concept of ultrafine particles known as U descriptors. See **ISO TC-209 certification; quality-system regulation.**

clearance See **design clearance.**

cliché See **printing, pad-transfer.**

clicking See **cutter, die.**

clogging See **geotextile; landfill and degradation.**

closed-die forming See **forging.**

closed-loop control See **control, closed-loop.**

closure **1.** A structure or device that is designated to close off the opening of a container and prevent loss of contents. Properties of plastics, such as a combination of flexibility and rigidity, provide different capabilities for the closures, such as snap fit with ease of removal. See **packaging. 2.** A compression joint; a closure or joint designed so that a sealing action is obtained by compressing an elastomer component. See **design hinge, integral; joining. 3.** In filament winding, the complete coverage of a mandrel with fiber. When the last tape circuit that completes the mandrel coverage is laid down adjacent to the first without gaps or overlaps, the winding pattern is said to have closed. See **filament winding. 4.** In grouting, the achievement of the desired reduction in the grout take by splitting the hole spacing. If closure is being achieved, there will be a progressive decrease in grout take as primary, secondary, tertiary, and quaderary holes are ground. See **plastic grout.**

closure, medical See **medical seal and closure.**

cloth See **fabric, nonwoven; fabric, woven; preform.**

coagulant A substance that initiates the formation of relatively large particles in a finely divided suspension or assists in gel formation with the result of accelerated settling of the particles or their deposition on a substrate. See **anticoagulant agent; gel.**

coagulation **1.** The physical or chemical change that induces a transition from a fluid to a semisolid or gellike state. **2.** The irreversible agglomeration of particles originally dispersed in a latex; precipitation of a plastic dispersed in a latex. See **anticoagulant agent; fiber, rayon viscose; latex, natural rubber; latex precoagulum.**

coal A black or brownish black solid combustible substance formed by the partial decomposition of vegetable matter without free access to air. It is formed from carbon, hydrogen, and oxygen. Moisture, pressure, and temperature (such as from lush and swampy forests) during the formation of the earth's crust influenced its production. It was a source of organic materials for the production of organic chemical intermediates used in the manufacture of plastics. They include benzene, toluene, phenol, and xylene. See **cracking; oil and gas; plastic raw material to product.**

coal and energy efficiency See **energy efficiency.**

coalesce To combine into one body or to grow together.

coalescence See **anticoagulant agent.**

coal tar A thick, black liquid obtained from the destructive distillation of coal. Organic products are produced that include raw materials in the production of certain plastics such as coumarone-indene plastic. See **bitumen.**

coating A layer of paint or film applied for functional, protective, decorative, adhesive, and many other reasons. See **cleaning; coating method.**

coating, acrylic emulsion See **acrylic emulsion.**

coating, air atomization A method that uses an air gun and a high-velocity air stream to break up a liquid plastic coating. Diameters of all droplets are less than 15 μm, with the average at 5 μm permitting good control of thickness. Its disadvantage is considerable overspray (poor transfer efficiency) unless electrostatic assist is used. See **coating, centrifugal atomization; coating, electrostatic spray; foamed polyurethane; spray-paint coating.**

coating, air-drying alkyd plastic The coined term *cyclyd* refers to cyclic alkyd coatings used in air-drying maintenance paints and baking metal primers. See **alkyd plastic; paint; primer.**

coating, air-knife A technique that is especially suitable for use with thin aqueous plastics such as adhesives, where it provides accuracy in metering and uniformity of application. A high-pressure jet of air is forced through orifices in the knife under controlled conditions. See **coating, knife.**

coating, antifouling A plastic coating or paint compounded with principally copper naphthenate and mercury for use on parts subjected to submersion or immersion in water, such as bottoms of ships, to protect them from attack by barnacles and other marine organisms. See **marine application; pigment.**

coating, anti-icing See **polyphosphazene plastic.**

coating, antistatic See **antistatic agent; moisture, humectant agent.**

coating, barrier See **barrier plastic.**

coating, bitumen See **bitumen.**

coating bottle with glass See **barrier, glass-coating.**

coating, calender See **calendering coating.**

coating, cast A coating that is applied in reverse where it is transferred from one surface to the surface where the coating remains. An example is the plastic cast coating on a substrate such as plastic film, paper, or aluminum foil. Also called *transfer coating.*

coating, cellulose lacquer A liquid coating material containing as the basic film-forming ingredients cellulose esters or ethers and plasticizers. See **cellulose ester plastic; lacquer.**

coating, cement A surface that is coated by tumbling or immersing metal parts, such as nails, in plastic or shellac. This produces a bond between the driven nail and the surrounding wood and is not removed when the nail is driven into the wood. Thus, it reduces the rusting of the nail during storage and while in service.

coating, centrifugal atomization A method that uses a centrifugal atomizer that consists of a rotating disk or bell. The plastic spray flows to the periphery of the rotor and disintegrates as it leaves the rotor's edge. The atomization is generally poor, and the paint direction is difficult to maintain, but the process is very efficient mechanically. To improve atomization, the rotor speed must be increased to a very high level, and electrostatic assist is used. See **air atomization; foamed polyurethane.**

coating, centrifugal or rotational **1.** An external method. The external surface of a product, such as a pipe, is coated. The coating is applied by feeding powder from a feed-roll or vibrator-type feeder while the preheated part is being rotated. See **casting, centrifugal.** **2.** An internal method. Powdered plastic is placed or metered into the inside of a heated rotating object and fused or solidified forming, for example, an inside tank liner or pipe. See **rotational molding.**

coating chrome See **chrome plating.**

coating, coil A method of plastic coating a coil substrate material. It is used extensively in different markets such as building products, transportation, containers and packaging, appliances, and furniture fixtures and equipment. About 200,000 T of coil is used principally using almost 80wt% of steel and almost 20% of aluminum. Different methods of coating are used such as paint or flame spraying, fluidized bed, flock spraying, and plastisol dipping. See **coating, fluidized bed; flocking; paint; plastisol.**

coating, conformal See **encapsulation.**

coating cratering Depressions on coated plastic surfaces usually are caused by excess lubricant additive in the coating compound.

coating, crocked Crocking is the removal of a dye or pigment from the surface of a paint or textile by rubbing or attrition.

coating, curtain A method of coating that usually uses a low-viscosity thermoplastic in solution, suspension, or emulsion in which the substrate to be coated is passed through and perpendicular to a free falling liquid curtain. The flow rate of the falling liquid and the speed of the substrate passing the curtain are controlled to provide the desired coating thickness. Also called *waterfall coating.* See **extruder coating and lamination; roll coating.**

coating, defective A defect. Defects can have picturesque names that become important when an explanation is needed. Names include chalking, cratering, fisheye, floating, flocculation, flooding, mooning, orange peel, pinhole, and wrinkle. See **defect; troubleshooting flaw.**

coating, dielectric See **parylene plastic.**

coating, dip A method of applying a plastic coating by dipping the heated metal part to be coated into a tank of plastisol or melted plastic for a specified time, removing it from the tank, and then chilling the adhering melt. Also called *dip casting.* See **casting, dip; forming, dip; polyvinyl chloride dispersion plastic.**

coating, dispersion The process of applying a flexible barrier material, suspended or dispersed in a vehicle that is usually water, to a surface in such a way that a continuous, coalesced, adherent layer results when the vehicle liquid is evaporated.

coating doctor blade See **doctor blade.**

coating electrical spark test See **test, coating electrical spark.**

coating, electrodeposition The precipitation of a material on an electrode as a result of the passage of an electric current through a solution or suspension of the coating material. The electrode is in the shape of the desired product. An important advantage of this process is that very complex products can be coated with rather exact thickness control. It offers very high corrosion protection of metals and compliance with environmental regulations. It is used for coating parts of various sizes including steel building trusses, car bodies, furniture, appliances, toys, and nuts and bolts. Also called *electrocoating* or *electroplating.* See **nickel.**

coating, electrophoretic deposition See **electrophoretic deposition.**

coating, electroplating See **electroplating.**

coating, electrostatic-spray A method of coating. Coating thicknesses are in the range of 3 to 30 mil (0.08 to 0.8 mm) depending on the service performance required of the part. In this process a dry-coating plastic powder is withdrawn from a reservoir in an air stream and electrostatically charged in a high-voltage corona field of a spray gun. The charged particles are attached to the grounded product (metallic or surfaced conductive plastic part) to be coated and adhere to it by electrostatic attraction. The coated substrate is then placed in a heated oven, and the coating is fused and bonded to form a continuous film. When the powder builds to a certain thickness, usually about 0.8 mil (0.2 mm), a dielectric barrier is created, and more powder is rejected. The part is heated prior to the application of additional coatings. This method reduces volatile organic compound (VOC) emissions by up to 70% over air-atomized and mechanical spraying systems and also produces less waste. See **air atomization; carbon black, conductive; coating, air atomization; powder coating; spray, centrifugal.**

coating, enamel See **enamel.**

coating, Engel-process A process that starts using a cold mold filled with plastic powder such as polyethylene plastic. The closed mold is placed in an oven operating from about 260 to 400°C (500 to 750°F), with the higher temperatures preferred. Thickness of fused plastics is determined by temperature, heating time, and to some extent the density and melt index of the plastic. The mold is cooled by spray or immersing in water. See **fusion.**

coating, engraved-roll See **printing, gravure.**

coating, fabric A method of coating fabric with a plastic to supplement desirable or improved properties of the fabric. In woven or knitted fabrics, the yarns almost always need to be sized or lubricated to eliminate problems during weaving. However, prior to coating they are removed and may require a finish to obtain coating to fiber bonds. Different methods are used for coating that depend on desired properties and cost. Processes include extrusion coating, calendering, knife coating, and fluidized techniques. See **calendering coating, frictional; test, fusion Kling; twist, direction of yarn.**

coating, fabric woven, vinyl See **vinyl seagoing bag.**

coating, flame-spraying A method of applying coating in which finely powdered plastic, together with suitable fluxes, are projected through a cone of flame onto the surface. See **flame; powder coating.**

coating, flocking A decorative or sound-deadening coating in which finely dispersed fibers of different materials are attached to the surface of a plastic part. Fiber can be oriented in specific directions and patterns determined by the process, such as spraying used and adhesive patterns laid down on the surface of the part. See **flocking.**

coating, flood A simple dry-powder technique for coating shaped and hollow articles where minor variations in coating thickness are not objectionable. A nonfluidized bed is a form of flood coating. See **powder coating.**

coating, flow A painting process in which an article to be painted is passed under a curtain of lacquer. The part is withdrawn and rotated until the coating dries.

coating, fluidized-bed A method in which thermoplastics are suspended in an open top box containing an air stream flowing up usually through a porous bottom plate containing the powder. The small plastic powder in the air behaves like a liquid mix. The part to be coated is heated and immersed in this fluidized bed. The plastic melts and fuses to the hot surface, forming a smooth coating. After the required time period the part is removed and cooled. See **catalyst, fluid; extruder, Ballatini process; powder coating; sintering.**

coating, fluidized-bed metal stripping A fluidized-bed stripping system that is used to remove solidified plastic from metal tooling such as plasticator screws, barrel vent ports, plugs molds, dies, and screen filters. This action can reduce downtime and cleaning costs. See **cleaning.**

coating, foam See **foam inverse lamination.**

coating, foil See **injection molding, in-mold.**

coating, fouling See **coating, antifouling.**

coating, frictional See **calendering coating, frictional.**

coating, fusion See **test, fusion Kling.**

coating, gravure See **printing, gravure.**

coating, heat protection See **coating, intumescent.**

coating, hydrocarbon plastic See **plastic, hydrocarbon.**

coating, icing See **polyphosphazene plastic.**

coating imperfection See **sensor, dynamic accuracy.**

coating, in-mold decorating, labeling A plastic that is introduced into the mold cavity to provide surface improvements such as a protective coating or a smooth surface as well as decoration and information. See **injection molding, in-mold; in-mold decorating; molding, coating in-mold.**

coating, in-mold paint See **paint coating, in-mold.**

coating, intumescent A plastic-type formulated coating with an intumescent action to protect a product from the intense heat of flames by decomposing into a foam barrier. This sprayed surface covering on a combustible material delays ignition and reduces flame spread when exposed to flames. At high temperatures, chemical reactions within it form a thick and tough inert layer. Some coatings protect to at least 1,100°C. See **ablative plastic; flame retardant.**

coating, kiss-roll A method of coating in which the plastic, in fluid form, is picked up by a roll and transferred to a secondary roll from where it is transferred to a substrate. By using this technique, very thin coatings can be achieved resulting in reduced plastic consumption. See **extruder roll coating, kiss.**

coating, knife A method of coating a continuously moving web (fabric, paper, film, aluminum foil), where the thickness of the coating is controlled by an adjustable knife (also called *bar*) set at the required spacing from the web and a suitable angle with the substrate. There are many variations of this basic technique, and they vary according to the product required. See **coating, air-knife; embossing spanishing.**

coating, knife-over-roll A knife coating technique in which the knife or bar is located above a backing roll carrying the substrate.

coating, light sensitive See **printing, photomechanical coating.**

coating, liquid (LC) A system that uses conventional spray equipment or dip-coating systems. The industry uses water-based (primarily) and solvent-based systems. The preferred water-based system results in no solvent fumes. Not all materials lend themselves to water-based systems. See **coating, dip; spray-paint coating.**

coating material The plastic that is used to meet different performance and processing requirements as well as cost requirements. The materials used include amine alkyds, thermoset acrylics, acrylic films, TS polyesters, solution vinyls, vinyl films, vinyl foams, modified silicones, epoxies, phenolics, plastisols and organosols, and fluorocarbons. See **plastic material type.** The applicable plastic coating protects metals from corrosive environments, impacts, abrasions, and provides ultraviolet resistance and decoration.

coating, metallizing A method of coating plastics with metals for decorative or functional purposes. Processes used include electroless plating, flame and arc spraying, sputtering, and vacuum. See **metallizing plastic.**

coating method The method used to meet different requirements. The most popular for high production is by extrusion and calendering. The processes used include air knife, calender, cast, dip, doctor roll, electrodeposition, electron beam, electroplating, electrostatic spray, emulsion, encapsulation, engraved roll, extruder, flocking, fluidized, foam, gel, gravure, in-mold, kiss-roll, metallizing, offset, overcoating, painting, powder, reverse roll, roll, rotational, sinter, solution, solvent borne, spraying, sputtered, vacuum, and waterborne. See **calender; extruded coating and lamination; extruded wire and cable; injection molding, in-mold; primer.**

coating, microencapsulation A method of individually coating particle matter for protection against environmental influences. In the broadest sense, it provides a means of packaging, separating, storing materials on a microscopic scale for later release under controlled conditions. See **drug application; drug, controlled-delivery; encapsulation; medical-device packaging clarity.**

coating, mold See **mold-cavity coating.**

coating oven See **festooning oven.**

coating, oxygen-barrier removable A gas-barrier coating for polyethylene terephthalate plastic that can be removed during recycling. This is an option in the oxygen-sensitive food-packaging market. Applications include beer, fruit juices, and tomato-based products. PPG's (Pittsburgh Plate Glass) coating is a thermoset two-component epoxy-amine plastic that is tough and humidity resistant. The coatings, colored or not, can be removed by contact with conventional cleaning solutions during reclaiming operations. See **barrier plastic; blow molding.**

coating, paint See **paint.**

coating, photoelastic See **test, nondestructive photoelastic stress-analysis.**

coating, pinhole-free See **xylylene plastic.**

coating, plasma A method in which a high temperature is established in an inert gas such as nitrogen and a coating powder is introduced at the periphery of the plasma. The particles melt and are propelled at high velocity to the substrate, where they form a film. See **plasma arc treatment; powder coating.**

coating, printing offset See **printing/coating, offset.**

coating, profile See **extruder profile.**

coating protection See **screw wear protection; surface treatment.**

coating, radiation See **polymerization, photo; radiation.**

coating, rain erosion See **rain erosion.**

coating reinforced concrete rod See **coating, steel-rod.**

coating, reverse-roll A method of coating in which the coating material is premetered between a pair of rolls, one of which deposits the coating onto the substrate. Adjusting the gap between the rolls or varying the speed of the coating roll can control the thickness of a coating.

coating, roll See **roll coating; roll covering.**

coating, roller The process of coating substrates with fluid plastics, solution, or dispersion by contacting the substrate with a roller on which the material is spread. The process is often used to apply a contrasting color on raised lettering or markings. See **roll.**

coating roll, kiss See **extruder coating and lamination; extruder roll coating, kiss.**

coating, sinter A method in which the metal product to be coated is first heated and then immersed into a plastic powder, such as PTFE or nylon, so that the plastic becomes fused on to the metal. Then it is withdrawn and heated to a higher temperature to complete the fusing action. See **coating, fluidized-bed; extruder, Ballatini process; fusion.**

coating, slush See **casting, slush-molding.**

coating, solid A high-solid (close to 100%) liquid plastic, predominantly acrylic, that is sufficiently fluid for application but cures with the application of radiation or heat. See **acrylic plastic; heat; radiation.**

coating, solution A method of plastic coating plastic film. Coating compounds (plastics, additives, and fillers needed) are dissolved in appropriate solvents. Baths are normally kept at room temperatures, but they may require elevated or lower temperatures depending on the compound's capability. Coatings are applied by continuous processing equipment. The thickness of the coating is controlled by various means depending on the specific coating process. When film is run directly into a coating bath, doctor rolls with controlled openings between the roll control the thickness after the film leaves the bath. Film speeds and bath consistency also influence thickness. Films may be coated on one side by using one roll immersed in the bath and transferring the coating to the second roll that is in contact with the film. Using flexographic rolls with controlled engraving patterns, uniform coatings will depend on depth of the engraving pattern. In the knife process, coatings are applied in large excess onto the surfaces of films, and the excess is removed with a knife or doctor blade. See **printing, flexographic.**

coating, solvent See **ethyl acetate; solvent, hydrocarbon; solvent, latent.**

coating, solvent-borne See **solvent-borne coating.**

coating, solventless See **powder coating.**

coating, solvent-resistant See **cellulose triacetate plastic.**

coating spark test See **test, coating electrical spark.**

coating, spray See **spray coating; spray-coating transfer efficiency.**

coating, spread A process that passes the material (film, sheet, etc.) to be coated over a roller and under a long blade or knife. The plastic coating compound is placed on the substrate or material just in front of the knife and is spread out over the material. The coating thickness is controlled by the speed the substrate travels under the knife, the space positioning between substrate and knife, and the viscosity of the compound. Also called *knife spreading*.

coating, steel See **recycling steel with vinyl scrap.**

coating, stress-strain calibration See **test, nondestructive stress-strain measurement, brittle lacquer technique.**

coating, sputtered A process for depositing permanent metal coatings onto plastic substrates to provide industrial and decorative capabilities. The term *sputtering* describes the removal of metal atoms from a base (metal) material utilizing a bombardment action. The bombardment is made of ions from gaseous sources such as argon and controlled within a magnetic field. The metal atoms coat all surfaces exposed. When compared to vacuum metallizing, its chief advantages are the ability to deposit a variety of metals on plastics and much thicker coatings. See **electroplating; metallizing, vacuum.**

coating static See **antistatic agent.**

coating, steel-rod A method of using steel rods to reinforce concrete and avoiding corrosion deterioration in certain environments, such as near salt water. Plastic, particularly polyethylene, is used as a coating or cover to protect the steel. See **composite; concrete, reinforced.**

coating, stress-strain test See **test, nondestructive stress-strain measurement, brittle lacquer technique.**

coating, strippable A temporary plastic coating that is applied to finished products (plastic, steel, aluminum, decorative panels) to protect them from damage, such as abrasion, corrosion, or scratches, during shipment, storage, and handling up to when they are stripped.

coating surface See **orange peel.**

coating, thickened See **thickening agent.**

coating tool See **tooling coat.**

coating, vacuum A method of depositing a coating using vacuum vapor techniques, either by physical or chemical vapor-deposition methods. Physical methods include evaporation and sputtering; chemical methods include polymerization through pyrolysis and glow discharge (plasma). Materials used can be solid or gas, and the type of energy applied either thermal or plasma. Sputtering employs a solid target and a plasma energy source. See **polymerization, electron beam; polymerization, ion-beam; tooling coat.**

coating, vacuum-deposition The process of coating by evaporating a metal under high vacuum and condensing it on the surface of the substrate to be coated. The vaporized material travels in all directions from the source and condenses on the plastic surface.

coating vehicle See **vehicle.**

coating, water-borne system A system of solutions in which 80% of the liquid is water. Aqueous systems have three categories: those in which the binder is soluble in water, those in which they have a colloidal dispersion, and those in which it is emulsified to form a latex. Water-soluble binders are low-molecular-weight plastics (5,000 to 10,000), colloidal-dispersion plastics have 10,000 to 50,000, and emulsion plastics have 10^6 or more. The emulsion types have the best film properties and resistance to water. The water-soluble binders have the poorest in these respects, and the colloidal are intermediate. See **organosol nonaqueous dispersion; polymerization, aqueous; water-aqueous.**

coating, water-resistant See **polylactic plastic.**

coating weight The weight of the coating per unit area varies per the industry requiring the coating. In the United States usually it is per ream, such as 500 sheets 23 in. × 36 in. or 3,000 ft^2 (64 × 90 cm or 280 m^2), but sometimes it is only 1,000 ft^2 (93 m^2).

coaxial electrical cable See **electrical cable button.**

cobalt-60 An unstable isotope that is used widely as a source of gamma radiation. See **gamma radiation; radiation.**

cobalt napthenate A powder that is used as a catalyst in bonding rubber to steel and other metals as well as paint and varnish drier. Also called *cobaltous napthenate*.

cobwebbing A filmy, weblike build-up of dried plastic, ink, or other material that appears on the doctor roll, end of an impression roll, and so on.

Coca-Cola bottle Acrylonitrile-styrene (AN) plastic was used in 1958 to produce the first commercial stretched Coca-Cola carbonated beverage bottles (two-liters). The glass pinch bottle debuted in 1915 was resurrected out of plastics. Production was by Monsanto Co. using Barex plastic from Sohia of BP Chemical International and DuPont's stretched injection blow-molding process. After production started in about eight plants on the East Coast, AN was banned by the U.S. Food and Drug Administration because of possible food contamination, even though its permeability requirements could not be determined by instrumentation available at the time. Rumors had it that competitors fed the FDA the wrong information. After significant cost and decades of experimentation, AN received approval. It was the forerunner of using PET plastics in an avalanche of bottles that appeared commercially worldwide beginning in the 1970s and continuing today. See **acrylonitrile-styrene plastic; blow molding, stretched; Coor's beer bottle; polyethylene terephthalate plastic; risk, acceptable packaging.**

cocatalyst See **accelerator.**

coconut shell An organic noncellulose material that has been reduced to a grit for polishing plastics or in a flour form used as an additive.

cocuring See **reinforced plastic cocuring.**

code See **bottle code system; container code system; recycled plastic identified; *Unwritten Laws of Engineering: The Professional Code for Engineers.***

coefficient of cornering The ratio of a cornering force to the vertical load. See **load.**

coefficient of cubic expansion See **coefficient of linear thermal expansion.**

coefficient of damping See **damping coefficient.**

coefficient of elasticity The reciprocal of Young's modulus in a tension (modulus of elasticity). Also called *tensile compliance.* See **modulus of elasticity; test compliance.**

coefficient of expansion A measurement change in length or volume of a part; specifically a percent change measured by the increase in length or volume of a part per original unit length or volume. See **coefficient of linear thermal expansion; melt flow.**

coefficient of friction The measure of the resistance to sliding of one surface in contact with another surface. A value is calculated under a known set of conditions, such as pressure, temperature, operating speed, material, and surface condition. The target is to develop a number relationship for either static or dynamic loading of the resistance of the material to slide or roll. The lower the number, the higher the material's lubricity. See **additive, slip; friction; lubricant; lubricity.**

coefficient of friction, kinetic The friction under conditions of macroscopic relative motion between two bodies. It is the ratio of tangential force, which is required to sustain motion without acceleration of one surface with respect to another, to the normal force, which presses the two surfaces together.

coefficient of friction, static The ratio of the force that is required to start the friction motion of one surface against another to the force, usually gravitational, acting perpendicular to the two surfaces in contact. See **friction; static.**

coefficient of gas permeability The volume of a gas flowing normal to two parallel surfaces at a unit distance apart (thickness), under steady-state conditions, through a unit area under a unit pressure differential at a stated test temperature. An acceptable unit is 1 cm^3 (at standard conditions)/s · cm^2 · cm Hg/cm of thickness at the stated temperature of the test (generally 23°C). See **barrier plastic; coefficient of permeability; test, permeability.**

coefficient of linear thermal expansion The change in volume per unit volume resulting from a change in temperature of the material. The mean coefficient is commonly referenced to room temperature. It is expressed in mm/mm °C (in/in. °F). See **expansion, linear; thermomechanical analysis.**

coefficient of optical stress The constant of proportionality between the stress in a material and the birefringence resulting from the molecular orientation produced (stress-optical law). See **birefringence; molecular structure; stress.**

coefficient of permeability (CP) The cm^3 of vapor at standard temperature and pressure (STP) permeating through a barrier material of unit area (cm^2) and unit thickness (cm) under a partial pressure difference of one cm Hg per unit time (s), regardless of the mechanism used. Thus CP is (ml @ STP) (cm) (cm^2) (s) (cm Hg). Since CP in these units have values for most plastics in the range of 10^{-7} to 10^{-12}, many large number units have been used in practical application studies. The most common of these is in units of g mil/$m^2$24 h · atm. Since CP is often highly temperature dependent, values should be quoted at a given temperature. With organic vapors, and often water vapors, the CP is dependent on the vapor pressures themselves, and it is necessary to specify the exact conditions of measurement. See **barrier plastic; coefficient of gas permeability; test, permeability.**

coefficient of scatter The rate of increase of reflectance with thickness, weight per unit area, at infinitesimal thickness of material over an ideally black box. See **black box; gloss; light scattering.**

coefficient of shear The reciprocal of Young's modulus in a shear test. Also called *shear compliance.* See **shear.**

coefficient of thermal conductivity The amount of heat that passes through a unit cube of material in a given time when difference in temperature of two faces is one degree, identified as the K factor in units of Btu · ft/(h · ft^2 · °F) or W/(m · K). See **thermal conductivity.**

coefficient of thermal expansion See **coefficient of linear thermal expansion.**

coefficient of viscosity The shearing stress necessary to induce a unit velocity gradient in a material. In actual measurement, the viscosity coefficient of a material is obtained from the ratio of shearing stress to shearing rate. This assumes the ratio to be constant and independent of the shearing stress, a condition satisfied only by Newtonian fluids. Consequently, in all other cases that include plastics, values obtained are apparent and represent only one point in the flow chart. Also called *Newtonian viscosity.* See **viscosity, coefficient, Peltier.** The reversible heat that is absorbed or evolved at a thermocouple junction when unit current passes in a unit time. See **thermocouple.**

coercive field See **electrical coercive field.**

coextrusion The simultaneous processing of two to seven plastic melt streams meeting in a die or mold to produce laminated plastic products. Product performances gained are a combination of what each individual plastic provides. The lay-up can include recycled material or low cost material that will reinforce more expensive materials in strength, tear resistance, and so on. It produces products (such as extruded film, sheet, cable covering, and pipe) where two or more different or similar plastics go through a single die. Two or more orifices from each extruder processing the different plastics are arranged so that the extrudates merge and weld together into a single structure prior to cooling. Each ply of the coextruded laminated structure imparts a desired property such as impermeability or resistance to some environment, heat stability, toughness, tear resistance, lower cost, and so on. See **blow-molding coextrusion foam; blow-molding coextrusion or coinjection; coextrusion tie layer; die, coextruding; coinjection molding; ethylene n-butyl acrylate copolymer plastic; extruder-blown film die, coextruded; extruder blown film die, coextruded; film, reflective; gasoline tank permeability.**

coextrusion capping A method of using the extrusion process to produce a plastic product that is topped or capped with another plastic.

coextrusion foam core A method of creating low-density foam-core products, such as pipe. The thicker wall can reduce material costs without sacrificing performance. In fact, properties can be improved by using the sandwich design advantages. See **blow-molding coextrusion foam; design, sandwich construction; foam; sandwich construction.**

coextrusion melt Some melt problems can be compensated for by making plasticator and die or mold adjustments. Interfacial instability is caused by an unsteady balance of shear forces. Examples of problems include (1) different melt temperatures of adjacent layers, (2) plastic viscosity differentials that should not be greater than 2-4/1, and (3) keeping the minimum thickness of a cap (top) layer to 5 to 10% of the total thickness because it is subjected to a high shear stress. There is a tendency for the less viscous plastic to migrate to the region of high shear stress in the flow channel, causing an interface deformation. When greatly different viscosities exist between adjoining layers, the less viscous tends to surround or encapsulate the other plastic; resulting in fuzzy interfaces, orange peel, and so on. See **melt.**

coextrusion safety alarm A method to alert the operators of a coextrusion line if one of the extruder drives trips out. This will prevent extrudate from back flowing into the stopped machine and creating a blockage in the feed section that could become hazardous.

coextrusion tie-layer A plastic tie-layer that is used when no bonding layers are desired in a coextruded composite structure. Choosing the proper adhesive layer is by no means a simple task since evaluation includes processability, bonding capabilities, and performance in the final coextruded product. There are many different types with different capabilities, with ethylene-vinyl alcohol copolymers being one of the important ones. See **barrier plastic; tie-layer.**

cohesion **1.** The propensity of a single substance to adhere to itself; the ability to resist partition from the mass; internal adhesion; the force holding a single substance together. **2.** The internal attraction of molecular particles toward each other. See **adhesion; molecular adhesion.**

coil coating See **coating, coil.**

coin impact test See **test, nondestructive impact RP coin typing.**

coining **1.** See **injection-compression molding. 2.** The mechanical reshaping of part surface. It is usually a secondary operation with forming techniques such as providing deep draw. See **design hinge, integral; forming. 3.** The peening over or compressing of a material to change its original shape or form.

coining hinge It is possible to create living hinges in some of the tougher engineering thermoplastics by the coining techniques. A molded or extruded part is placed in a fixture between two coining (shaped) bars. Pressure is applied to the bars sandwiching the hinged area with or without heat. The part is compressed to the desired thickness that is usually 0.012 to 0.020 in. (0.03 to 0.05 cm) with melt flow occurring perpendicular to the hinge. Molecular orientation occurs to provide the bending action. Also called *cold working.* See **design hinge, integral.**

coinjection molding Joining together two injection molding barrels by a common manifold and nozzle through which both melts flow before entering the mold cavity. (More than two plasticators can be used.) The nozzle is usually designed with a shutoff feature that allows only one melt to flow through at any controlled time. The first melt shot to enter the cavity would provide the skin. The second melt shot would provide the core, and if desired the third step would take the melt used in the first shot to apply a skin over the final entrance of the second shot to completely enclose the part with a continuous skin. If adhesion between the plastics does not occur, a tie-layer is used. It provides an excellent way to integrate or entrap recycled contaminated plastic with one side or both sides using a barrier virgin plastic. Also called *double-shot injection molding, sandwich construction molding, sandwich molding, multiple-shot molding, structural foam molding, in-molding,* and *two-color.* See **barrier plastic; blow-molding coextrusion or coinjection; coextrusion; injection molding; injection molding, foamed low-pressure coinjected; injection molding, sandwich; injection molding, two-shot; tie-layer.**

coinjection molding, single-plasticator A nonconventional molding method that uses only one single-screw barrel. It is called (by Addmix Ltd., London UK) *sequencing screw loading.* The system feeds different but compatible plastics volumewise through the injection-molding machine's feed throat in a predetermined computer-controlled sequence that is maintained as the materials travel through the screw. The first plastic entering the cavity forms the aesthetically pleasing skin of the part and the second fills out its core. Any slight degree of mixing of the plastics that might occur is buried in the core.

coinjection tie-layer See **coextrusion tie-layer.**

coke **1.** The carbonaceous residue resulting from the pyrolysis of pitch. See **fiber, carbon. 2.** Capitalized, an abbreviation for Coca-Cola. See **Coca-Cola bottle.**

coke dust An organic nonfibrous material used as a filler. See **filler.**

coking Refinery recycling at a high temperature where the batch-process (coker) units are favored in refining heavy feedstock.

cold-bend test See **test, cold-bend.**

cold-cure foam See **foam, cold-cure.**

cold-cut varnish See **varnish, cold-cut.**

cold drawing See **forming, cold drawing.**

cold-fed extruder compounding See **mixer, extruder.**

cold fit See **ice, dry.**

cold flow See **flow, cold.**

cold forming See **forming, cold.**

cold-gas polishing See **polishing, cold-gas.**

cold heading A process for forming plastic rods into rivets by uniformly loading the shaft end or projection in compression while holding and containing the shaft trunk. Heat is sometimes used. All thermoplastics can be thus formed. Acetal and nylon are particularly suitable and used. See **joining rivet; staking.**

cold molding See **molding, cold; thermoforming, comoform cold-forming/molding.**

cold preform molding See **blow molding, injection preform.**

cold pressing See **press, cold.**

cold resistance A synonym for *freeze-off* or *freeze resistance.* See **freeze-off.**

cold runner See **mold runner, cold (for thermoplastic); mold runner, cold (for thermoset plastic).**

cold setting A plastic that will assume an immobile state at near ambient temperatures without the application of heat from an outside source.

cold-setting adhesive See **adhesive, cold-setting.**

cold shot See **extruder cold shot.**

cold slug See **molding cold slug.**

cold stamping See **stamping.**

cold stretch A pulling process designed to improve the mechanical properties of filaments, sheets, films, pipes, and so on. Also called *cold drawing.* See **orientation, cold stretching.**

cold worked hinge See **coining hinge.**

cold working Any form of mechanical deformation processing carried out on a plastic below its crystallization temperature. See **crystallization.**

collapsible bottle See **design, collapsible-bottle.**

collapsible core See **mold, collapsible-core.**

collapsible squeeze tube See **tube, collapsible squeeze.**

collapsing frame See **extruder-blown film.**

collet **1.** A rigid, lateral container that is used for thermoforming sheet material. See **thermoforming. 2.** A dam or restriction box that is used to collect melt during certain fabricating operations. See **mold. 3.** The drive wheel that pulls glass fibers from the bushing or spinneret; a forming tube is placed on the collet and a package of strand is wound on the tube. See **fiberglass. 4.** A metal band, ferrule, collar, or flange that often is used to hold a tool.

colligative property The property of a solution that depends on a number of solute particles but not on their nature. See **solute.**

collimated Rendered parallel. See **roving, collimated.**

collimator In resinography, a device for controlling a beam of radiation such that its rays are as nearly parallel as possible. See **resinography.**

colloidal Being in a state of suspension in a liquid medium in which extremely small particles are suspended, dispersed, and not dissolved and do not settle. This motion is caused by impact of molecules of the liquid on the colloidal particles. The continuous zigzag motion of these particles is known as the *Brownian movement.* Elastomer latex is an example of colloidal suspension. See **aerosol; deflocculation; latex; material, powder; micelle; suspension.**

colloidal carbon See **carbon black.**

colloidal mill See **mill, colloidal.**

colloidal solution See **solution, colloidal.**

colloidal ultrafiltration The separation of colloidal or very fine solid materials by filtration through microporous or semipermeable mediums.

colophony See **rosin.**

color and light See **light.**

color and ultraviolet stabilizer See **ultraviolet stabilizer and color.**

colorant A dye or pigment. The dyes are synthetic or natural compounds of submicroscopic or molecular size, soluble in most common solvents, yielding perfectly transparent colors. The pigments are organic or inorganic substances with larger particle sizes and usually insoluble in the common solvents. They are used to provide conditions such as coloring plastics for aesthetic qualities, color matching, ultraviolet stability, strength, electrical properties, and resistance to migration (bleeding). They may either be naturally present in a material, admixed with it mechanically, or applied in solution. A valid distinction between dyes and pigments is almost impossible to draw. Some have established it on the basis of solubility or on physical form and method of application. Dyes are fairly soluble in plastics, while pigments, being insoluble, are dispersed throughout the mass. The choice depends on plastic compatibility or the need for solubility. Color stability is important, which means that the color is stable at processing temperature and on exposure to light and moisture when in use. Certain colorants, such as heavy metals (lead, cadmium, mercury), can present a problem in waste disposal. They can constitute a toxic residue following incineration if they are not properly handled and disposed. Safer alternatives are being used based on environmental requirements. See **additive; bleed; carbon black; channel black; dye; extruder color changeover; fixing agent; hue; iron oxide pigment; melt vibration; pigment; titanium dioxide.**

color, apochromatic See **lens, apochromatic.**

coloration, dis- **1.** A change in the original color of a material. **2.** The lack of uniformity in a color that should be the same over the entire surface of a material.

color bleed See **bleed; colorant.**

color changeover See **extruder color changeover.**

color, channel black See **channel black.**

color concentrate See **concentrate.**

color corrected lens See **lens, apochromatic.**

color decoration See **blow molding, extruder blow-action; film decorating.**

color dispersion See **pigment, color dispersion in.**

color-dispersion staining The color effect that is produced when a transparent part, immersed in a liquid having a refractive index near that of the part, is viewed under the microscope by a transmitted light and precise-aperture control exists. See **stain, antioxidant non-.**

color, dry The lowest-cost method of coloring plastics. Dry colorants have one major disadvantage: they tend to be messy and dusty. Very careful handling and blending are required.

color evaluation The assessment of color quality. Color-evaluation technology continues to improve, moving toward allowing the industry to rely on machines rather than the trained eye. Since machinery imperfections can exist, the eyes still have it. See **black; spectrophotometer.**

color fadeometer An instrument that is used for determining the resistance of materials to fading. This apparatus accelerates the fading by subjecting the product to high-intensity ultraviolet rays of about the same wavelength as those found in sunlight.

color-fast Having the ability to resist change in color, particularly in outdoor ultraviolet light. See **light resistance.**

color formulation The creation of pigments. The transition from heavy-metal-based inorganic pigments to more environmentally friendly substitutes has progressed steadily. Pigments based on cadmium and lead now represent about 20% of the market. These types can be used in nearly any kind of plastics and provide a full range of yellow, orange, and red shades. The organic pigment and dye and non-heavy-metal inorganic pigments substitutes to date have limitations such as heat stability, color strength, opacity, light fastness, and dispersibility.

color, freeze-dry A pigment that is dispersed in a vehicle that solidifies at room temperature or when chilled. Pigments are usually commercialized in flake or chip forms.

color hopper See **hopper, color.**

color hue See **hue.**

colorimeter An instrument for matching colors. It produces results that are about the same as those of visual inspection but more consistent. The sample is illuminated by light from the three primary color filters and scanned by an electronic detecting system. It is sometimes used in conjunction with a spectrophotometer, which is used for close control of color in production. Also called *color comparator* or *photoelectric color comparator.* See **postconsumer plastic; spectrophotometer; test, color; yellowness index.**

colorimetry, visual A procedure for determining the color of an unknown material by visual comparison to color standards. See **gas burn.**

coloring agent See **pigment.**

coloring, dry A method that is commonly used to color plastic by using a drum to tumble blend uncolored particles with selected dyes and pigments.

color, iron-oxide pigment See **iron-oxide pigment.**

colorizer, de- See **carbon black, animal.**

color, Kubelka-Munk theory See **computer color matching, Kubelka-Munk theory.**

colorless dye A synonym for *optical brighter.* See **optical brightener agent.**

colorless oxygen resistant See **polyarylene ether phosphine oxide plastic.**

color-light source See **light metamerism.**

color loader See **hopper, color.**

color masterbatch See **compound, masterbatch.**

color matching The process of accessing colors. Continued efforts to improve spectrophotometers' hardware and software have greatly improved the usefulness of the spectrophotometers, but the instruments have not been able to replace people who have color-matching experience. See **colorimeter; computer color matching, Kubelka-Munk theory of spectrophotometer.**

color migration The movement of dyes or pigments through or out of a material. See **bleed; colorant.**

color mismatch See **light metamerism.**

color mixing See **compounding; extruded-blown film die, coextruded-reflective; mixing evaluation.**

color molding, two-shot See **injection molding, two-shot.**

color, mottle A mixture of any irregular colors or shades that produces a more or less distinct or complicated pattern effect (specks, spots, streaks). See **screw marbleizing.**

color, pastel A tint; a mass tone to which white has been added.

color pellet sorter See **pellet color sorter.**

color pigment See **pigment.**

color pigment dispersion See **pigment, color dispersion.**

color reflectance See **iridescence.**

color removal See **decolorizing agent.**

color saturation See **saturation.**

color segregation A succession of clearly defined wavy lines of color on the surface, which do not match the color of the remaining areas and produce the illusion that the product is comprised of separate pieces.

color selection The selection of pigments for a plastic product. Color selection is important for reasons other than aesthetics. For example, the surface temperature of a product exposed to sunlight is dependent on its color.

color shade A lightness difference between surface colors whose other attributes are essentially the same. Shade is derived from shadow and so should be applied only to change toward darker color. In practice, reference is made to lighter as well as darker shades.

color sorter See **pellet color sorter.**

color, special-effect A pigment or dye that is used to produce visual effects other than color. These effects include metallic, pearlescent, fluorescent, and phosphorescent. Aluminum-based materials are used to get silvery metallic colors, and copper alloys are used to obtain goldlike metallic appearances. To get pearlescence or nacreous effect, a platelike pigment, with a high refractive index, is required, such as lead carbonate. Fluorescent colorants can give a more brilliant color than ordinary dyes and pigments as they absorb invisible light and emit it as visible light. Phosphorescent colorants behave in a similar way, but they emit light as an afterglow—that is, they glow in the dark. See **glass sphere, solid; phosphorescence; pigment, fluorescent pigment, metallic; pigment, pearlescent.**

color spectrum See **spectrum.**

color stability and processing Avoiding color shift by controlling melt temperature and, to a lesser degree of significance on both the mean and variance, melt flow and melt pressure. See **melt temperature.**

color standard Accuracy in color for a plastic. A very high degree of accuracy is required. Color chip samples are used for matching, but special instrumentation is available to ensure exact color matching when required. With or without concentrates, it is important to know what additives are used and their reproducibility in production based on how the equipment is set up (temperature, etc.). See **black; Macbeth apparatus.**

color striation See **striation.**

color test See **color standard; test, color; test, organoleptic taste.**

color tint An even-tone area of a solid color.

color, titanium dioxide See **titanium dioxide.**

color, transparent See **printing ink, transparent.**

color value The lightness of a color. A color may be classified as equivalent to some member of a series of grays ranging from black (the zero member) to white.

color, white See **calcium carbide; titanium dioxide.**

column crush See **load column crush.**

combination mold See **mold, family.**

combustible Being able to burn regardless of a material's autoignition temperature or whether it is a solid, liquid, or gas. See **combustion, autoignition point; fire; flammability; incineration; landfill and degradation; nonflammable material; test, tunnel fire.**

combustible, non- Being unable to flame or produce ignitable vapors.

combustion An exothermic oxidation reaction that may occur with any organic compound as well as with certain elements. An example is controlled burning of solid wastes for (recoverable) disposal. Another is using an oxygen-starved process via pyrolysis to produce combustible solid and gas fuels that can be burned to generate energy. See **back flash; carbon monoxide; combustion, autoignition point; fire; flame extinguished; flammability; heat of combustion; ignition; pyrolysis; pyrophoric material; smoke emission.**

combustion, autoignition point The minimum temperature required to initiate or cause self-sustained or self-ignition combustion in any substance in the absence of a spark or flame. It is caused by an internal, chemical exothermic reaction. Also called *spontaneous ignition* or *self-ignition.* See **exotherm; pyrophoric material.**

combustion efficiency The ratio of heat actually developed in a combustion process to the heat that would be released if the combustion were perfect.

combustion modular unit An incineration device of low capacity. Small waste-to-energy systems can be created. See **incineration.**

command system The set point or the reference input to a control system. See **control system reliability.**

commingled plastic See **recycling commingled plastic.**

comminute To reduce size of particles by methods such as grinding or pulverizing. See **abrasive; granulator; material, powder.**

commodity plastic A higher-volume, lower-priced plastic that has low to medium properties. It is used for less critical parts where engineering plastics are not required. About 90wt% of all plastics are commodity types. See **engineering plastic; plastic.**

communication The transmission and reception of data among processing equipment and upstream to downstream equipment. See **control actuator; electronic doppler effect; I/O device.**

communication protocol A set of rules governing communication or transfer of data between computer hardware and software. When related to plastic primary and secondary processing equipment, communication includes reference to exchange of process controls, meeting standards, following production schedules, and so on that permits the interchanging of action such as molding machines with auxiliary equipment. The target is to have a worldwide exchange interface as set up among the trade associations, SPI, Washington, DC, and Euromap, Frankford, Germany. See **auxiliary equipment; fabricating process type; test, white-box and black-box.**

communication protocol, auxiliary equipment **1.** Devices that require minimum configuration or data, such as chillers, dryers, or loaders. **2.** Devices that require large amounts of configuration or data, such as robots, sensors, and mold and die controllers.

communication protocol interface The information that is required to monitor and configure a manufacturing operation and is distributed among various units of auxiliary equipment. This information is transferred to the central control. Communication interfaces and communication protocols have been developed to allow the information to be exchanged. Successful communication requires a durable interface and a versatile protocol. A communication interface must be both mechanically and electrically durable.

communition A mechanical shredding or pulverizing process of solid waste or waste water. See **granulator; waste.**

comoforming See **thermoforming, comoform cold forming/molding.**

comonomer A monomer that is mixed with one or more different monomers for a polymerization reaction that results in a copolymer. See **catalyst, metallocene chemistry; copolymer.**

compact disc (CD) A digital-storage medium that is used with music and computer data. This large worldwide marketable product includes high-density CDs (HDCDs), twin-faced CDs, multilevel CDs, floppy disk, and so on. They are precision injections molded from special, easy-flowing polycarbonate with cycle times of seconds, such as 5 to 10 sec. They are common types of storage devices where data are written and read. A variety of floppy discs are used. Also called *computer disc.* See **birefringence; digital versatile disc; magnetic-optical technology; phonographic record; polycarbonate plastic; recording media.**

compacting **1.** The progressive compacting of materials by the use of a rolling mill or other device. Also called *powder rolling.* **2.** See **compressibility.**

compaction **1.** A process that is used to compress materials (virgin, waste, recycled) to reduce their bulk density for use during fabrication or to reduce the materials volume to save space. See **bulk factor; compounding, shear roll; density, bulk; granulator; material handling; solid waste volume reduction; waste compaction.** **2.** In reinforced plastics and composites, the application of a temporary vacuum bag and vacuum to remove trapped air and compact the lay-up. See **reinforced plastic vacuum bag molding.**

company success See **World of Plastics Reviews: Making Marketing Work.**

compatibility The ability of two or more materials to combine with one another to form a homogeneous composition (without separation) that has improved properties compared to the individual materials. See **material, microphase structure; solubility and molecular weight.**

compatibility, bio- See **biocompatibility.**

compatibilizer agent An agent that makes useful blends of dissimilar plastics, including recycled plastics. If natural compatibility is missing, a plastic can be chemically modified, such as by grafting, to improve reactivity with another plastic, or a third agent can be added to do the blending. Two-component and multicomponent mixtures are used. The most common agents are block or graft copolymers and polymer cosolvents. See **blending; grafting; polymer, reactive.**

competition and management See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

competitor pooling See **legal matter: patent pooling with competitor.**

complete information management See **management, complete information.**

complex agent A compound that combines metallic ions to form complex ions. See **compound; ion.**

complex ion An ion that contains a central metal cation bonded to one or more molecules or ions. See **ion.**

compliance **1.** The reciprocal of the tensile modulus of elasticity. See **modulus of elasticity.** **2.** The reciprocal of shear modulus. See **shear modulus.** **3.** The evaluation of stiffness and deflection of material. See **deflection; stiffness.**

component **1.** A separate compound that is one of at least two compounds. See **compound.** **2.** A part of a whole system; for example, reinforced plastic with the reinforcement and plastic. See **reinforced plastic.**

composite A combination of two or more materials with properties that the components do not have by themselves. Wood is a composite of cellulose fibers held together with a matrix of lignin. Steel reinforced concrete and medical pills are composites. Included are reinforced plastics. In this book the term *reinforced plastic* is used to denote a composite of reinforcement (usually in fiber form) with a plastic matrix. Other plastics compounds are laminated plastic films.

During the 1940s the Society of the Plastics Industry started the Low Pressure Industries Division, which shortly thereafter became the Reinforced Plastics Division under the direction of Charlie Condit and in 1954, with D. V. Rosato's leadership, the Reinforced Plastics/Composite Division. It is currently called the Composites Institute. The original product was glass-fiber-thermoset polyester plastic RPs. To date about 90wt% of all RPs continue to be glass-fiber-TS polyester plastics.

Composites may be identified and classified many hundreds of ways. There are aggregate-cement matrix (concrete), aluminum film-plastic matrix, asbestos fiber-concrete matrix, carbon-carbon matrix, carbon fiber-carbon matrix, cellulose fiber-lignin/silicic matrix, ceramic fiber-matrix ceramic (CMC), ceramic fiber-metal matrix, ceramic-metal matrix (cermet), concrete-plastic matrix, fibrous-ceramic matrix, fibrous-metal matrix, fibrous-plastic matrix, flexible reinforced plastic, glass ceramic-amorphous glass matrix, laminar-layers of different metals, laminar-layer of glass-plastic (safety glass), laminar-layer of reinforced plastic, laminar-layers of unreinforced plastic, metal fiber-metal matrix, metal matrix composite (MMC), microsphere glass-plastic matrix (syntactic), particle-ceramic matrix, particle-metal matrix, particle-plastic matrix, potassium nitrate-charcoal-sulfur matrix (blasting powder), plastic-plastic (coextruded, coinjection, laminated), silver-copper-mercury matrix (dental amalgam), steel-rod-concrete matrix, whisker-metal matrix, whisker-plastic matrix, wood-plastic matrix, and many more. See **automobile, composite; bamboo; carbon-carbon composite; coating, steel-rod; concrete, reinforced; dental amalgam; hybrid; injection-molding nonplastic; mold; plastic and the future; plastic-concrete composite; reinforced plastic; reinforced plastic, advanced; reinforced-plastic future; reinforced plastic process; skin, synthetic; wood-plastic impregnated.**

composite, boral A composite consisting of boron carbide crystals in aluminum with a cladding of commercially pure aluminum. It is in reactor shields and neutron curtains.

composite, ceramic matrix (CMC) A material that consists of ceramic or carbon fiber surrounded by a ceramic matrix, usually silicon carbide (SiC). See **ceramic.**

composite, cermet A composite material of two components—(1) an oxide, carbide, boride, or similar inorganic compound and (2) a metallic binder that is interdistributed in any of various geometrical forms.

Composite Institute An organization that represents the reinforced plastics industry and is part of the Society of the Plastics Industry. In the late 1940s it started as the Reinforced Plastics Division of SPI. See **composite; reinforced plastic.**

composite-metal matrix (CMM) A material that provides performance advantages over monolithic metals. It is used in metal wire and other reinforcements such as whiskers. See **injection-molding nonplastic.**

composite, nano- A composite that contains very tiny platelets of a special type of surface-modified clay called *montmorillonite.* This reinforcing filler is dispersed in a thermoplastic or a reactive liquid plastic. The clay particles are one nanometer thick (40 billionth of an inch). Only 2 to 5wt% of the nanoclay is required to obtain high-performance properties. Nanoclays have been used in paints and various organic fluids.

composite variation, reliability factor See **material variation, reliability factor.**

composition The elemental and chemical components that make up a material and their relative proportions. See **material.**

composition board See **wood composition board.**

compost An organic material that mixes food, sewage, sludge, and yard wastes with soil and in which aerobic bacteria have broken down the waste to an intermediate humuslike state. The end product is often used as a soil conditioner. Decomposition is accelerated by adding starch, ammonia bicarbonate, and so on. See **biodegradable type; biodegradable waste; separator, balisic; starch degradable; waste.**

compound An intimate mixture of a plastics with all the materials necessary, such as additives required to fabricate a product. Yearly U.S. consumption is about 11×10^9 lb (5×10^9 kg) with 35% PVC, 28% color compounds/concentrates, 19% reinforced/filled, 9% TPE, and 9% other blends and alloys. The annual U.S. market of at least $9 billion by end product is 26% automotive, 24% building and construction, 14% packaging, 12% appliance, 10% electrical/electronic, and 14% others. See **additive; blending; bulk factor; chemical compound; compounding; density, bulk; filler versus unfilled compound; mixer; plastic consumption; plasticizer; plasticizer, internal; reinforced-plastic bulk-molding compound; reinforced-plastic prepreg; reinforced-plastic sheet-molding compound; screw mixing and melting; unsaturated compound; yield, theoretical.**

compound, batch The product of one mixing operation as distinct from continuous processing. See **compound, masterbatch; computer batch processing; mixer, batch.**

compound, bulk molding See **bulk-molding compound; reinforced-plastic bulk-molding compound.**

compound coordination A compound that is formed by a Lewis acid-base reaction in which a metal atom or ion is the electron acceptor.

compound curing test See **test, scorch Mooney.**

compound, dry-blend A free-flowing dry compound containing all necessary additives prepared without fluxing or the addition of a solvent. Also called *powder blend.* See **blending.**

compounded, pre- Preloaded with a specially designed plastic. The term usually applied when special complex loading equipment is employed.

compound, electrical See **plastic, electrically conductive.**

compound, electron-deficient See **electron-deficient compound.**

compound-extruder mixer See **extruder compound mixing.**

compound fine See **fine.**

compound, -ide A compound that ends with the suffix-*ide* (sodium chloride, calcium chloride) contains only two elements. See **element.**

compounding A method used to compound plastics through dry blending, melt mixing, or both using batch or continuous methods. Batch systems tend to be more labor-intensive and less complicated to operate and control. Continuous systems are more consistent and easier to instrument for statistical process control. Extrusion equipment, predominantly twin and other multiscrew types, provides the major source for compounding. Equipment usually operates at rates ranging from 500 to 5,000 lb/h (230 to 2300 kg/h). Compounding is usually carried out at high rates because costs are reduced. Large extruders are required where screws could range up to at least 12 in.

(300 mm) in diameter. Compounding is performed by plastic material suppliers, in-house by fabricators (converters), and companies that specialize in compounding. Usually the compounding is done for a specific product application.

During compounding a variety of equipment is used to meet specific needs, such as (1) ingredient storage, weighing, preblending (box, bin dischargers, tippers, tilters, power compactors, dryers), (2) extrusion continuous mixing (feeders, gear pumps, screens, filters, heating/cooling systems, recycling systems), (3) size reduction (pelletizers, dicers, granulators, choppers), (4) downstream equipment (material handling, water strippers, pellet cleaners, screens, classifiers, inspection systems), (5) product storage, packaging (baggers, loaders, containers), and (6) test laboratory (testing capabilities, analytical equipment, color matching equipment, light booths, quality controls). Most of all the 17,000 plastics available worldwide undergo compounding to meet product requirements. Over 65wt% of all the worldwide 150 million tons (340 billion lb) consumed are estimated to be compounded in designed extruders and batch-type mixers. The thousands of different additives and other ingredients used in the compounds improve the plastics performance during processing or meet the many different product requirements (including cost). The composition of the compound is dictated by the requirements of the converter's application. See **plastic consumption.** See **activator; binder; blender; blending; calendering material; complex agent; compound; compounding; extruder compound mixing; extruder, multiple-screw; extruder, twin-screw; filler versus unfilled compound; generic; kneading; masticate; mill; material blending letdown ratio; mixer; mixing; peptizer; polymer; reactive; rubber; scavenger; thickening agent; titanate coupling agent; tolerance and shrinkage; vulcanization.**

compounding, shear-roll A unit that is suitable for homogenization, melting dispersion, compression, and pelletizing plastics. The actual process takes place in the adjustable gap between two rolls rotating in tandem. Surfaces of both rolls have many longitudinal grooves across their faces and spiral grooves designed to shear and transport the plastic. Rolls have independent temperature controls across their entire length. See **mill, roll; mixing; pelletizing; roll; shear.**

compound intermediate A compound that is in itself not useful or of little primary importance but is used as a stepping stone for the preparation of another product.

compound, ionic See **ionic compound.**

compound, masterbatch A homogeneous mixture of a plastic matrix and one or more materials in known proportions for use as a raw material in the preparation of fabricated parts. It usually contains a high concentration of an additive or additives. Masterbatch is designed for use in appropriate or very specific quantities so that the correct (accurate) end concentration is achieved, such as color matching. See **compound, batch; mixer, batch.**

compound odor See **odor.**

compound, organic A compound containing carbon in its molecule. See **chemical synthesis; ether; organic.**

compound, organic volatile See **volatile organic compound.**

compound, peroxy A compound that contains oxygen-oxygen linkage. See **chemistry.**

compound, premix A preloaded ready-to-use strand in bulk or molding compound forms that is made with standard plastics, usually on simple operating equipment. With proper storage condition of temperature, its shelf life can be controlled. Also called *gunk molding material.* See **mixer, medium- and low-intensity; plastic material; recycled material property; reinforced molding compound.**

compound, saturated. See **saturation compound.**

compound, sheathing A material, such as cable coverings, that provides protection of products against electrical transmission, wear resistance, and so on. See **sheathing.**

compound, sheet-molding See **sheet-molding compound.**

compound uniformity The compounding of different-size mechanical-type particles, such as with recycled plastics alone or mixed with virgin plastics, so that they are uniformly compounded to obtain maximum performance. See **mixer.**

compound, unsaturated See **unsaturated compound.**

compound, volatile organic See **volatile organic compound.**

compreg See **wood, compreg.**

compregnate To impregnate and simultaneously or subsequently compress, as in the production of compregs and aluminum casting. See **impregnation.**

compressed wood See **wood, compressed.**

compressibility The ability of a material to be compressed. It is usually reported in conjunction with recovery and does not indicate behavior of a material under prolonged load. See **creep; elastic stability; test, compression property; thermal data.**

compressible melt See **thermodynamic property.**

compression buckling A mode of failure generally characterized by an unstable lateral material deflection due to compressive load action on the structural element.

compression crush test See **test, container column crush.**

compression mold A mold that is open when the material is introduced and that shapes the material by heat and pressure of closing. See **mold; mold cavity, compression.**

compression molding A technique for molding thermoset plastics. Usually preheated material (dielectric heater, etc.) is placed in a heated mold cavity. The mold is closed under pressure, which causes the material to flow and completely fill the cavity. Chemical cross-linking occurs, solidifying the molding material. See **air entrapment; automation; blow molding, stretched operation specialty; bonding; thermocompression; clamping; clamping, daylight-opening; clamping platen, book-opening, clamping platen, rotary; cleaning; coating, in-mold decorating, labeling; cross-linking network characteristic; wiring, post-; eutectic mixture; exotherm; film, skived; heating, dielectric; heating, pre-; injection-compression molding; isotactic plastic; loading edgewise; material charge; modulus, compression; modulus of elasticity; mold breathing; mold cavity, compression; mold cavity pressure; mold, compression; mold dehumidification; molded-part cosmetics; mold flash; molding; molding, isostatic; molding, match metal; molding pressure required; mold well; operation, automatic; operation, manual; operation, semiautomatic; outgassing; plastic consumption; platen; preform; press, press rotary; pressure, locking; process control; processing, art of; processing-line downtime; processing-line system; processing window; reinforced-plastic, molding; reinforced-plastic, XTC; safety machine lockout; screw compression ratio; screw transition zone; shot; shot, short; sintering; soluble-core molding; strain; stress; test, compression property; test, melt-flow spiral; thermoforming, solid-phase pressure; thermoset plastic; tracer; transfer molding; venting; yield point.**

compression-molding charging tray A tray designed to charge simultaneously with plastic material all the mold cavities of a multiimpression mold. The device can operate by using a tray with openings where the material is placed (manually or usually automatically) and in turn a withdrawing sliding bottom tray that initially closes the openings and slides exposing openings matching the top tray so material drops into the cavities. Also called *loading tray*. See **material charge.**

compression-molding cut-off The line where the two halves of a compression mold come together. Also called *flash groove* or *pinch-off*.

compression-molding inching The easing of pressure on the molding material just prior to its final closing action. See **mold inching.**

compression molding, screw preplasticator A screw unit, next to the mold, that preheats materials, particularly bulky materials such as bulk-molding compound. A controlled amount of heated material can be automatically directed into the cavity or cavities. These screws do not require any special design such as in an injection-molding machine or extruder. See **plastication, pre-.**

compression molding, vacuum A vacuum chamber around or within the mold that removes air and other gases from the cavity. Applying a vacuum in a mold cavity can be very beneficial in molding plastics at low pressures. See **reinforced-plastic vacuum bag molding; vacuum press.**

compression plane strain A method of loading the central area of a sheet specimen by compressing it between the faces of two molds or dies with rectangular cross-sections. Thus, the area of the specimen being stressed is constant, so that the true, not nominal, stress is the most readily calculated. Also, unlike uniaxial compression, the friction between molds and dies and the sample remains constant with increasing strain. It may be necessary to correct for edge effects. See **strain.**

compression set The residual deformation of a material after removal of the compressive stress or load.

compression shape factor The ratio of the loaded volume or area to the force-free volume or area.

compression test strength The ability of a force [MPa (psi)] that tends to crush or buckle a part; the ultimate compressive load divided by the original cross-section of a test specimen. See **strength; test, compression property.**

computer acceptability Information produced via computer- aided design, computer-aided manufacturing, and computer-aided engineering that may require a password. See **programmable-controller safety; safety.**

computer accessibility See **programmable-controller safety.**

computer acoustic holography The storing and integrating of homographic images by computer. The image provides full characterization and details of buried flaws. See **digital; holography.**

computer address The label or number identifying the memory location where a unit of information is stored in a computer disk or tape.

computer-aided Assisted by a computer. It implies that the task is done faster than it would have been done without the computer in developing a product that is practical or accurate in representing an idea. See **art and science; definition, art of; design analysis; design technology; experience and science; graphic art; people's challenge; productivity; risk, acceptable; scientific method.**

computer-aided design (CAD) A method of designing the critical characteristics of a part, mold, or die via a computer. This method is susceptible to geometric and topological anomalies when creating complex surfaces and solids. These problems may not surface until well downstream of design such as during analysis, rapid prototyping, data exchange, numerical-control programming, or other manufacturing applications. See **design; prototype, rapid.**

computer-aided design drafting See **artwork; graphic art.**

computer-aided engineering (CAE) The engineering design analysis, system modeling, simulated structure analysis, finite-element analysis, and so on that improve product quality and lower product development time and cost. See **CAMPUS database.**

computer-aided laboratory (CAL) A work environment that uses computers in evaluation. Computers are used in specific instrument methods. The analyst or user has the prime responsibility to set up requirements to be met and ensure that complete and reliable data are obtained. See **ISO-9000 certification; laboratory accreditation.**

computer-aided manufacturing (CAM) A system that can take a computer-aided design product, devise the essential production steps, and electronically communicate this information to manufacturing equipment to reduce lead time and leads to more efficient material use, improved inventory, etc. See **fabricating; computer-integrated manufacturing; fabricating process; FALLO approach; maintenance; manufacturing execution, system; troubleshooting.**

computer-aided molecular graphic (CAMG) Computer software that facilitates the investigation of the properties of macromolecules by graphically creating virtual-reality versions of the molecules. Research utilizing these models has been very useful both timewise and costwise. See **designing with plastic tailor-made models.**

computer-aided process planning (CAPP) A method that supports steps of manufacturing planning such as choosing the best or available machine for the job, programming delivery of raw materials, and so on.

computer-aided quality control (CAQC) A method for performing tests at fast speeds with an unusually high degree of accuracy. It provides information such as rapid data collection, data analysis and reporting, statistical analysis, process control, testing, and inspection. See **quality and control.**

computer-aided testing (CAT) A system actively involving for the computer in testing that can take place in all stages of product development from design through production to product final evaluation. See **test; test, nondestructive.**

computer-aided tomography (CAT) A diagnostic technique using x-ray photographs in which the shadows of structures before and behind the section under scrutiny do not show by other methods. Technically, it is the process that produces an image in a plane of an object without interference from the adjacent planes. See **digital imaging; test, nondestructive.**

computer algorithm See **algorithm.**

computer analog-to-digital converter (A/D or ADC) A device that converts real-world analog data, as for transducers, into binary or digital form suitable for computer processing. See **computer servo control digital/analog; digital; drive-system control; motion-control system; servo control.**

computer annotation The process of inserting text on a drawing.

computer application program A computer program that accomplishes specific tasks, such as process control and word processing. See **process control.**

computer architecture The specific components of and the way those components are interconnected to make up a microcomputer system. The term is often used to describe the specific bus structure within a microcomputer. See **bus.**

computer arithmetic logic unit (ALU) A computer unit that performs the arithmetic and logic operations on data presented. Data are processed in the form of binary words, each word containing a specified number of binary bits. Arithmetic operations include addition and subtraction. Logic operations involve shifting all bits of a word to the left or right. See **mean, arithmetic.**

computer A-scan A method of data presentation on a cathode ray tube that utilizes a horizontal base line that indicates distance, or time, and a vertical deflection from the base line that indicates amplitude. See **cathode ray tube.**

computer assembly language A machine-oriented language in which mnemonics are used to represent each machine language instruction. Each computer central processing unit (CPU) has its own specific assembly language.

computer-assisted design and drafting (CADD) A design that uses a computer screen to provide enhanced quality and efficiency when compared to previously conventional plotting. It is used by industrial designers, design engineers, and architects. See **design.**

computer-assisted manufacturing See **computer-integrated manufacturing.**

computer-automated laboratory to production A single integrated circuit that is capable of providing centralized control and data manipulation for a number (hundreds) of attached devices or equipment. When a set of programmed instructions (a read-only memory) and some form of input and output for communication with the outside world are added, a fully functional microcomputer is created. See **automation; automation level; motion-control system; operation, automatic.**

computer-based training (CBT) An affordable video technology that makes training a large number of people easy and efficient. CBT allows plants to create in-house training programs that are easily updated. Video-based training limitations include its sequential nature: teaching units logically follow and build on one another, so a user's attempt to circumvent the predetermined sequence can be both time consuming and frustrating. Also, it is a one-way communication tool with the user maintaining a relatively passive role in the learning process.

A major advantage of CBT is that learning can take place at the conveyance of the consumer. These training methodologies can take a back seat to the multimedia-based training (multimedia based application [MMBA], computers and media working together), using audio, video, text, and graphics to take full advantage of a personal computer's ability to capture, reconfigure, and display data. They are efficient and effective, particularly in the area of technical training such as running complex or dangerous equipment in a safe environment. Real-life situations are depicted, and the learner is asked to respond. See **education; productivity; training; training versus education; website.**

computer batch A group of jobs that is to be run on a computer in succession, without human intervention.

computer batch file A computer program that consists of a text file containing several commands. When the file is run, each line command is executed serially.

computer batch processing The application of computer data-analysis techniques to the classification, assimilation, and interpretation of subjects such as plastic and chemical information. It is a method in which a computer program or set of related programs must be completed before the user goes on to the next operation. Its major purpose is to correlate data in such a way that trends or patterns are indicated. See **compound, batch; computers and statistics; control; fabricating process; microprocessor control; plant; plastic failure or successs; production.**

computer baud It is a unit of measure for the transmission speed of data over any serial link, such as a computer modem. One bit per second is a baud. There are standard rates such as 300, 1,200, 9,600, or 19,000 baud.

computer, bio- See **biological biocomputing.**

computer bit The smallest piece of electronic information used by a computer. The word comes from *binary digit;* a bit can be either 0 or 1. Eight bits make up a byte of information, and 16 bits make a word.

computer browser The software that is used for bringing up and displaying web pages. Two of the most commonly used browsers are Netscape Navigator and Microsoft Internet Explorer.

computer bulletin board system (BBS) A system that allows computer users to hold discussions and make announcements that others can read and respond to.

computer bus A communication network consisting of a parallel data path within the computer system that is shared by many system components. Usually described by the width of the parallel lines available, typical busses are 8-, 16-, or 32-bits in width. See **bus.**

computer chemometric The application of computer data-analysis techniques to the classification, assimilation, and interpretation of chemical information. It can correlate data in a way that indicates trends or patterns.

computer Chinese room A hypothetical situation that is used as a vehicle in the debate over whether computers can think.

computer chip See **integrated circuit, plastic; packaging, electronic.**

computer coinjection See **coinjection molding, single-plasticator.**

computer color matching, Kubelka-Munk theory of A theory of computer color-matching calculations. It is a phenomenological turbid-medium theory relating the reflectance and transmission of scattering and absorbing materials to constants and the concentrations of their colorants. See **colorant.**

computer communication protocol See **communication protocol.**

computer continuous processing The real-time processing of data on a continual basis. It often is used for process control and monitoring applications. See **process control.**

computer control A mode of machine operation. Its software process control sets the parameters of operation. See **fabricating asynchronous; numerical control; process control.**

computer control motion See **design, motion-control, mechanical and electronic effects.**

computer cost modeling See **technical cost modeling.**

computer data analysis, chemical See **computer chemometric.**

computer databank A collection of information held in a computer's memory whose data are handled by a database. See **computer database; computerized database, plastic.**

computer database A set of computer software programs that make it easy to handle data in different ways. It is an electronic filing system that allows users to put in any information; cross-reference, alter, delete, and add to it; and retrieve it in forms specified by the user. The database handles the data in the databank. *Database* sometimes refers to highly organized data, and *data base* refers to data without regard to organization. The usual is *database.* Also called *data management.* See **computer databank; computer monitoring information; computer software; data-management system; intelligent database; plastic material selection; technical writing; test.**

computer database binary A numerical representation in computer database technology of base 2 in which each digit can have only one of two possible values of 1 or 0.

computer database relation A linkage within a database that logically binds two or more elements in the database. For example, a nodal line (interconnect) is related to its terminal connection nodes (pins) because they all belong to the same electrical net. See **computer database.**

computer design approach See **computer-aided; definition, art of; design analysis; design, graphic; people's challenge; risk, acceptable.**

computer digit One of 10 Arabic numbers (0 to 9).

computer digital A numerical output device that indexes, number by number, from the initial output reading to the final output reading. It is more accurate than a similar analog device but slower. It gives an exact reading. See **analog; computer analog-to-digital converter.**

computer digital controller A microprocessor controller that converts signals from a pressure or temperature sensor to an output signal to a power unit to hold the sensor at the set point value. See **control drive, optimized; computer.**

computer digitized Converted into computer-readable form wherein all information units (letters, numbers, symbols, graphs, picture elements) are represented by on-off sequences of electronic impulses.

computer digit, significant A digit that is necessary to define a value or quantity.

computer disk See **compact disc.**

computer drawing A computer program that offers choices of mode functioning, such as positioning, grid choice, zoom, and line quality. See **artwork; graphic art.**

computer finite-element mesh operation An engineering method for determining the structural integrity of a mechanical part by mathematical simulation. Automatic mesh generation creates grid points and elements for specific regions of a model, allowing the creation of necessary data for finite-element analysis programs. See **finite-element analysis.**

computer graphic (CG) **1.** The application of the capabilities of a computer to the analysis and synthesis of engineering problems. **2.** The communication of solutions in a graphic form. See **design protection; graphic art.**

computer hardware The five standard hardware components of an electronic digital computer that are connected by the internal signal pathways that make up the bus. These units are the arithmetic-logic unit (ALU), the control unit, the input and output units (I/O), and the memory. The heart of a computer is the central processing unit and the arithmetic-logic unit. See **computer software; control system reliability; reliability.**

computer home page The introductory page of a computer website.

computer hypertext Computer text that can be linked to other text by clicking with a mouse at designated points.

computer hypertext transfer protocol (HTTP) The system of communication rules for the World Wide Web.

computer image-processor A computerized unit that is an important aspect of a machine vision system. It can be classified as configurable, task-specific, or custom/dedicated. Many have been designed for specific tasks such as gauging or pattern recognition. Also called *vision engine.* See **inspection, vision system.**

computer information processing See **computer monitoring information; plastic, smart.**

computer-integrated manufacturing (CIM) A system of using a computer or a system of computers that coordinates different (parts or all) stages of manufacturing through troubleshooting, which enables the manufacturer to custom design products efficiently and economically. All equipment and processes that have an effect on productivity, quality control, and so on are monitored and controlled by a central computer. The CIM addresses different functional aspects of plant operations that have an impact on productivity and quality. See **blow molding, extruder parison programmed control; computer-aided manufacturing; computer monitoring information; design, motion-control, mechanical and electronic effects; fabricating process; management, complete-information; quality control; troubleshooting.**

computer intelligence See **intelligence, artificial.**

computer Internet A collection of computer networks that are tied together into a massive worldwide electronic network. See **computer website.**

computerized database, plastic A software database. Extensive plastics databases are available but because they are not all prepared using uniform testing and reporting systems, users must analyze how the data are presented. See **computer database; intelligent database; plastic material selection; plastic consumption; test.**

computerized electronic document and retrieval system An automated system for document processing, retrieval, and storage. See **plant operation; process control; production data acquisition; storage.**

computerized knowledge-based engineering A method of engineering that incorporates computer software. Since computers still cannot translate human thought processes into computational and cognitive models that make intelligent computer-aided designs, the human-mind engineering approach to programming a computer continues to be essential. The activities of the human designers, such as alternating steps of abstraction and refinement to blue-sky thinking, are not easily codified into the computer program languages. See **algorithm; blow-molding innovation; computer software; design, innovative; engineer; modeling parametric; productivity; program; revolutionary versus evolutionary developments.**

computerized ultrasonic See **molded-material surface measurement.**

computer machine interface unit (MIU) A piece of computer hardware placed on or near a machine to collect and represent data from various sensors or microprocessor-based devices.

computer machine language The instructions that humans write so that a computer can execute directly (do its job when it is working). Also called *object code* or *object language.*

computer market size See **plastic industry size.**

computer measurement See **machine, coordinate measuring.**

computer, micro- A computer that is physically small.

computer, microprocessor control See **microprocessor control.**

computer modeling Three predominantly three-dimension methods of creating products and storing them in databases with different advantages and limitations. See **modeling; modeling, solid; modeling, surface; modeling, wire-frame; prototype.**

computer modem A computer accessory that connects to a telephone line and allows, as an example, communication between computers that are connected to fabricating equipment.

computer monitoring information A method of monitoring the fabricating machine information to improve a machine's productivity. In machine-productivity terms, information is the speed and ease with which data about a machine's performance can be integrated with the other information to provide a basis for control decisions. Transducers, servo control, and other devices can provide the data needed for diagnostics and production monitoring, increasing the machine's productivity. This information can then be provided through the factory network. See **computer database; production data acquisition; productivity; servo control; technology assessment; transduce.**

computer-multimedia-based training See **computer-based training.**

computer optical data storage (ODS) The technology for storage, processing, and retrieval of vast quantities of data. In various formats, ODS is suitable for applications of mass replication of predetermined data, long-term (over 10 years) archiving, recording of legally nonalterable records, and finite erasing and recording. Because ODS provides very high data density (such as up to 1 gigabyte/second on a 130 mm disk), removal from the drive, random access, and low cost per bit exists when compared to magnetic and micrographic storage devices.
computer packaging See **antistatic agent.**
computer Pascal A high-level, general-purpose computer language that is often used for scientific and business programs. See **Pascal.**
computer, personal See **personal computer.**
computer picture-level benchmark (PLB) A program for running graphics and display performance tests on a vendor's hardware. It measures the length of time needed to execute a series of transformations for a specific picture, or a set of two-dimension, three-dimension, or bitmap data suited for a particular application. A PLB program is available from the National Computer Graphics Association. See **artwork.**
computer plant layout See **designing plant layout via computer.**
computer plastic flow analysis See **design, die; design, mold.**
computer plotter A device that displays data output from a computer in graphical form. See **graphic art.**
computer procedure-oriented language (POL) An artificial language that is used to define, in a form understood by people, the actions required by a computer to solve a problem. Hundreds of programs have been developed, such as Ada, Agol, APL, Cobol, Fortran, and Pascal. For example, Ada was a new language for the 1980s developed by the U.S. Department of Defense as a language for all applications that included commercial and scientific. See **mathematics.**
computer processing control automation A method for applying precise control to any fabricating process. Clear physical relations can seldom be set up because the flow process are coupled with thermal and mechanical models. A valid description is usually achieved only by experiments such as trial and error. The important process parameters are changed one at a time to the limits of the working point. See **FALLO approach; molding area diagram; molding volume diagram; process control, adaptive.**
computer processing control, statistical (SPC) A system that starts with the premise that the specifications for a product can be defined in terms of the product's requirements or that a product is or has been produced that will satisfy those needs. Generally, a computer communicates with a series of process sensors or controllers that operate in individual data loops. The computer sends set points (built on desired performance characteristics for the product) to the process controller that constantly feeds back to the computer to signal whether the set of points are in fact maintained. The systems are programmed to act when key variables affecting product quality deviate beyond set limits. See **process control; quality control; statistical process control; tubing, microbore.**
computer processor See **processor, micro-.**
computer process simulator See **process simulator.**
computer program A list of instructions that a computer follows to perform a task. See **blow molding, extruder parison programmed-control; order.**
computer protocol, machinery See **communication protocol; test, white-box and black-box.**
computer, random access memory (RAM) A type of memory that can be both read and changed during computer operation. RAM is volatile so that power disruption or loss causes all the data stored to be lost.
computer rapid response See **manufacturing execution system.**
computer, read only memory (ROM) A type of memory that contains fixed data. The computer can read data but cannot change it in any manner.
computers The hardware and software that permeate all areas of the plastics industry from the concept of a product design, to raw material to processing, to marketing and sales, to recycling, and so on. Proper knowledge is required to use computer hardware and software efficiently. The fastest of today's computers are able to perform more than a billion calculations per second. Even so, they are still too slow to approximate the higher intellectual processes characterized by humans, such as the capacity to reason, discover meaning, generalize, and learn from past experiences, that require the nearly instantaneous making of numerous associations and generalizations. Computers are very useful tools, but the most important and essential part to have with the computer is qualified people. See **algorithm, recognition; computer-based training; computerized knowledge-based engineering; computer software; device, smart; integrated circuit; productivity.**
computers and cybernetics See **cybernetic.**
computers and innovation See **design, innovative.**
computers and plastic See **computers design.**
computers and statistics Computers make statistics a more flexible tool and help prevent "cookbooks" (the blind application of the same standard techniques no matter what problem exists). A statistical perspective can be a simple route to substantially increase productivity, quality, and profit. See **quality; statistic.**
computer science and algebra The symbolic system of mathematical logic called Boolean algebra that represents relationships between entities, either ideas or objects. George Boole (England; 1815–1864), first professor of mathematics at University College Cork, regarded as one of the greatest mathematicians of the 19th century, formulated the basic rules of the system in 1847. Boolean algebra eventually became a cornerstone of computer science. See **algebra; mathematics.**

computer servo control, digital/analog In the past the majority of servo systems used analog elements. Conversions have been made to digital systems. See **computer analog-to-digital converter; drive-system control; motion-control system; servo control.**

computer software Computer programs that perform tasks such as product design, processing techniques, mold and die design, management control, storage control, testing, quality control, cost analysis, and so on. Software helps with the jobs of product design, mold or die design, material selection, processing setup, and so on. Software programs can be purchased off the shelf or created inhouse. They are useful tools and can perform certain functions. See **auxiliary equipment; biological biocomputing; CAMPUS database; computer-based training; computer Chinese room; computer hardware; computers; control system reliability; COSMIC software; creativity; DART software; Deere JD/GTS software; EnPlot software; fabricating process type; FORTRAN software; GAIM software; legal matter: patent search; melt-flow analysis; mold-cavity melt-flow analysis; numerical control; order; process simulator; program; reliability; screw inspection; test data and uniform standard; training; vinyl composition tile; Appendix G, websites on plastics.**

computer-software limitations See **melt-flow analysis problem.**

computer-software white-box See **test, white-box and black-box.**

computer technical cost modeling See **technical cost modeling.**

computer, thinking See **computer Chinese room.**

computer tolerance analysis See **design and tolerance.**

computer virus A destructive program that invades and infects computer programs, causing them to malfunction or self-destruct.

computer warmware People in the computer industry.

concave surface See **shape, concave.**

concavity factor The relative amount that elastomer or rubber varies from Hooke's law ideal curve. It is determined as the ratio between the energy of the extension curve to the straight-line curve to the same point. The entire stress-strain curve of elastomer/rubber is concave toward the stress axis or away from the strain axis. See **modulus of elasticity; stress, elastic limit; stress-strain curve.**

concentrate **1.** A mixture of a measured amount of additives (colorants, lubricants, antistats, antifogs, antioxidants, biocides, blowing agents, ultraviolet stabilizers, etc.) and a specific plastic that is prepared usually in pellet form. Other forms include tablets, biscuits, and microporous carriers. This approach can provide an accurate mixture for mixing with the base plastics during processing. Care should be taken to verify that the concentrate plastic is compatible with the base plastic being processed. Usually the amount of concentrate used is about 1 to 4wt%. See **fragrance concentrate, material; pellet, micro-; plastic material; preform. 2.** To increase the amount of a dissolved substance by evaporation.

concentrate letdown ratio The ratio of a plastic concentrate material, such as a color additive to the basic plastic material. This ratio is usually identified as a percent by weight of both materials (wt%). See **material blending letdown ratio.**

concentricity **1.**Two circles or cylindrical shapes that have a common center and common axis, such as the inside or outside diameters of a barrel or outside diameters of the surface and bearing surfaces of a screw. Deviation from concentricity is referred to as *runout.* See **barrel inspection; mathematical closure error indicator movement; screw inspection; tolerance, full indicator movement. 2.** The relationship of all inside dimensions to all outside dimensions usually expressed in thousands of an inch or millimeter full indicator movement (FIM). Deviation from concentricity is usually referred to as a *runout.* The concentricity should allow for the maximum part tolerance. The geometry of the part should help indicate the tolerance applied. See **mathematical closure error; plasticator; screw. 3.** The relationship of all circular surfaces with the same center. **4.** See **runout.**

concentric-screw extruder mixer See **extruder, concentric-screw mixer.**

concrete A hard, strong building material made by mixing a cementing material, as portland cement, and a mineral aggregate, as sand and gravel, with sufficient water to cause the cement to set and bind the entire mass. To produce nonshrinkable concrete, plastic is included in the mix. Concrete has been used since at least the Roman Empire. See **aluminum stearate; plastic-concrete composite.**

concrete, cellular See **cellular concrete.**

concrete, injection-molding See **injection-molding nonplastic.**

concrete, nonshrinkable See **concrete.**

concrete-plastic composite See **composite; impregnation; plastic-concrete composite.**

concrete, reinforced A composite reinforced concrete that contains steel rods in various forms to significantly increase performance (strength, etc.) over unreinforced concrete. In areas in or near ocean salt water or big bodies of water, steel is protected from corrosion by a cover of plastic, usually polyethylene, or polypropylene. Steel rods can be prestretched during solidification of the concrete to provide increase performance over nonstretched steel reinforced concrete. See **coating, steel-rod; composite; directional property; orientation.**

condensable vapor See **vapor, condensable.**

condensate A product of condensation from the vapor phase.

condensation **1.** A chemical reaction in which two or more molecules combine. See **chemical reaction, condensation; polymerization, condensation. 2.** The process of converting a material in the gaseous phase to a liquid or solid state by decreasing temperature, by increas-

ing pressure, or both. Usually in air sampling only cooling is used. See **storage and condensation. 3.** The transformation from a gas to a liquid.
condensation agent A chemical compound that performs a catalytic action and furnishes a complement of material necessary for the achievement of the polycondensation of a plastic. See **polycondensate.** See **mold dehumidification.**
condensation, capillary The condensation of an absorbed vapor within the pores of the material. See **capillarity.**
condensation polymerization See **polymerization, condensation.**
condensation plastic A plastic formed by polycondensation (condensation polymerization). Examples include the alkyd, phenol-aldehyde, and urea formaldehyde plastics.
conditioning The process of bringing the material, product, or apparatus to required conditions (moisture, temperature, cleanliness, etc.) prior to further processing, treatment, inspection, or testing. Also called *conditioning cycle.* See **service condition; temperature conditioning.**
conditioning, pre- Any preliminary exposure of a material to specific atmospheric conditions, such as humidity and temperature, for the purpose of favorably approaching equilibrium with that prescribed atmosphere.
condition, initial A special type of boundary conditioning specified for time equals zero.
condition, service See **service condition.**
condom A prophylactic that is usually made from latex and PVC type but more recently also with polyurethane plastic.
conductimetry The scientific study of conductance measurements of solutions. To avoid electrolytic complications, conductance measurements are usually taken with alternating current.
conduction, heat In heat transfer, the migration of energy due to a temperature gradient. The movement of molecules transfers the heat energy to hotter or colder temperatures, with different degrees of thermal motion, into colder or hotter regions. See **convection; heat; heater; kirksite; radiations; thermal conductivity; thermodynamic.**
conductive carbon black See **carbon black, conductive.**
conductivity The transfer of electrical or thermal energy along a potential gradient. It is the reciprocal of volume resistivity—the electrical or thermal conductance of a unit cube of any material that is the conductivity per unit volume.
conductivity, electrical The mechanism of conductivity in plastics that has electrons traveling from point to point when under stress, following the path of least resistance. Most plastics are insulative; their resistance to electron passage is extremely high. Speed of electron movement depends on the additive/modifiers concentration and the degree of separation of the additive particles. Increasing additive content reduces interparticle separation distance, and at a critical distance, known as the percolation point, resistance decreases dramatically and electrons move rapidly. See **electrical conductivity; plastic, electrically conductive.**
conductivity, super- See **temperature conductivity, super-.**
conduit **1.** A tubular raceway for carrying electrical wires, cables, and so on. **2.** A pipe for conveying fluid.
cone See **textile cone.**
cone calorimeter test See **test, fire cone and lift.**
conference See **Appendix D, Worldwide Plastics Industry Events.**
confidence interval See **population confidence interval; population confidence level; population confidence limit.**
confidentially See **design protection.**
configuration See **chemical configuration.**
conflict of interest See **legal matter: conflict of interest; specification and standard limitations.**
conformal **1.** Representing small areas in their true shape. **2.** Leaving the size of an angle between corresponding curves unchanged.
conformal coating See **encapsulation.**
conformance See **quality optimization goal.**
conformation See **molecular conformation.**
conical dry blender See **blender, conical dry.**
conjugated See **chemistry, conjugated.**
conjugate plane See **optical conjugate plane.**
connector See **electrical connector; fastener.**
connector, female lure failure See **medical connectors, female lure failure in.**
conservation Plastics offer resource conservation benefits many different ways and in all marketed products, as described throughout this book. A few are listed here for cross-referencing. See **adhesive; building and construction; coating; energy; incineration; insulation resistance; medical; plastic consumption; packaging; market; recycling; waste.**
conservation of energy See **energy conservation; energy, law of conservation of; energy loss, machine; plastic and food.**
conservation of matter, law of A statement that the mass flow through any cross-section of a pipe is constant (applies to pipe conveying and material handling). An offshoot of this law is the continuity of flow through a pipeline equation. This equation states that the volume of discharge will be the same at any point within the pipeline. Because of this law, the density of air is assumed to be a constant when the pressure differential between the beginning of a pipeline and the end is less than 1% based on measurements utilizing absolute pressure. See **energy conservation; material handling; conveying, pneumatic.**
consignment Giving material to another supplier for use in manufacturing a customer's product.
consistency A property of a material determined by the complete flow-force relation. See **flow.**
consolidation A processing step such as the compressing fiber and matrix to reduce voids and achieve a desired

density. See **design consolidation and minimization of material.**

consolute Of or pertaining to liquids that are perfectly miscible in all proportions under certain conditions. See **material, microphase structure.**

consumption, plastic worldwide by type See **plastic consumption; Table 1, World Plastics Consumption in the Year 2000.**

constantin A copper-nickel alloy, wires of which are used in conjunction with wires of a different material (usually iron) in thermocouples for measuring temperatures. See **thermocouple.**

constant rate test machine See **tensile testing machine test rate.**

constituent Refers to an ingredient included in a plastic or compound such as other plastics, additives, fillers, or reinforcements.

constraints See **design constraints.**

constrained-geometry catalyst See **catalyst; polymerization catalyst.**

construction and building See **building and construction market.**

Consumer Product Safety Act See **legal matter: Consumer Product Safety Act.**

consumer goods See **energy efficiency.**

consumer testing See **test, organoleptic.**

consumption, energy See **energy consumption.**

consumption, plastic See **plastic consumption.**

contact adhesive See **adhesive, contact; adhesive contact angle; adhesive contact cement; laminate; lens, contact; plastic, contact-pressure; pressure, contact; reinforced-plastic molding.**

container A receptacle that contains material. They range from simple to very complex shapes. See **blow molding, extruder bottle volume adjustment; bottle; bottle lug; closure; gas effusion; load column crush; packaging; packaging container content misrepresentation; packaging dual-ovenable tray; packaging, hot fill; packaging pouch heat-sealed, wraps, and reusable containers; Petlite; recycling, automatic-sorting; recycling steel with vinyl scrap; spin trimming; tare; text, container column crush; tube, collapsible.**

container bead shape **Contoured container lip.** A good bead is designed to have a cross-section thickness similar to the side wall. It is shaped to hold a lid in place during handling and repeated recapping yet allow the lid to be removed without destruction or great effort. See **container lid skirt shape.**

container, Boston round The shape of a container, like a bottle, where its cross-section as well as shoulders are round.

container, buffer A material or device placed in a container to position or protect the contents from the force of impact.

container chime In packaging, the rim of a container such as a drum, barrel, or can.

container, choked-neck A narrowed or constricted opening in the neck of a container.

container code system Standards that have been established to identify plastic materials and to assist separators of plastic bottles and other products to create a higher value for recycled material. For example, the bottoms of bottles identify the most widely used plastics. See **bottle-code system; recycled plastic identified.**

container collapse The contraction of the walls of a container on cooling after manufacture, such as blow molding, leading to a permanent deformation of the container. See **green dot.**

container head space The space between the fill level of a container and the sealing plane.

container heel The part of a container between the bottom bearing surface and the side wall.

container heel radius The degree of curvature at the extreme bottom end of a container extending upward from the bearing surface. Also called *base radius.*

container leakage A defect. Prior to blow molding with its fast production lines, it was relatively easy and quick to check leakage (not including exotic tests for special products such as sensing porosity of metal castings) by sending pressurized air into the container and immersing it in a water bath. If no bubbles appeared, then it was presumed not to leak. Sophisticated leak detection equipment is used for the fast-operating lines. The methods depend on air or other gas as the test media and fall into the categories of achieved pressure test, pressure drop test, and displacement test. See **blow molding; bottle; dissociation; test, soap-bubble.**

container lid skirt shape A shape around the bead of the container that allows the lid to be removed without great effort and yet remains in place during capping conveying, insertion into cartons, shipping, warehousing, and repeated recapping. The design is critical in high-speed capping lines.

container lid, stacking or capping of It is best to always allow some stacking clearance between lids. Though a lid may have been designed with little or no stacking clearance and intended initially to be used in a shuttle or static-type feeder, a future requirement may dictate the part to be used on a spinning rod capper. Lids with no stacking clearance will act as a solid column and will not move along the spinning rods. When stacks of lids are packaged out of register, unnested, they will contain warpage and create capping problems in all types of capping equipment. See **warehousing.**

container market In U.S. plastic bottle shipments passed glass container shipments in 1994, but the metal container market share is almost three times larger than plastic bottle share. See **market.**

container neck-down A tapering, downward and inward, of a container body.

container nesting Containers can be molded with as little as $1/2°$ angle (draft) on the side wall, but those that are nested usually have a minimum of 5° angle. Angle, wall thickness, and stacking lug height primarily determine how much clearance will exist from one to the other.

container, oblong A shape where a container's rectangular cross-section is perpendicular to the major axis.

container, off-center Any condition where the finish opening is not centered over the bottom of the container. Also it is the condition where the mandrel is not concentric with the ring of the blowing head.

container, oil canning See **blow molding, extruder flat surface; oil canning.**

container, pour-out finish A container finish with an undercut below the top, designed to facilitate pouring without dripping.

container, recessed-panel A container designed with a label panel in which the area for labeling is indented or recessed. Adding or bonding a label could provide additional strength to the container (bottle, etc.).

container, refillable A container that is designed to be refilled as long as the container is not cracked, chipped, or uncleanable.

container, returnable A container that provides a financial refund that was included in the original purchase.

container, rocker A bottle with its bottom deformed so it does not stand solid (rocks).

container, round-square A shape of a container that has sides of equal width with well-rounded corners and shoulders.

container, top-load The amount of weight bearing on the top of a container. This term is sometimes used to indicate the maximum load the container will bear without becoming distorted.

container, wall thickness determination A method of measuring wall thickness. Various devices are used, including mechanical measurement by calipers, optical sensors, and different radiation sensors such as infrared.

contamination An unwanted or foreign body in a material or the processing area, including air, that affects or detracts from part's quality. See **cleanroom; electrostatic discharge detector; fiber processing filtration; lint; material contamination; material impurity; material inclusion; metal detection; packaging pouch heat sealed wraps, and reusable containers; pollution, air; purification; rail-car contamination; recycled paper; scavenger; sensor, inductive and capacitive proximity; waste.**

content, plastic See **plastic content.**

continuous phase See **mixture, continuous-phase.**

continuum mechanic See **Boltzmann superposition principle.**

contour package See **packaging, contour.**

contract See **fabricating outsourcing; government contract directory; legal matter: mold contractional obligation; legal matter: product liability law; legal matter: shop-right.**

contraction See **shrinkage.**

contractor See **vinyl composition tile.**

contract processor See **legal matter: processor contract.**

control In any process or experiment, the reference base with which the results are compared. The control represents known or target requirements of facts or figures. The use of a control is vital to provide interpretation of the final product. See **device, smart; process control; adaptive; quality optimization goal; sensor.**

control actuator The use of serial communications in conjunction with programmable logic controller to oversee machine operations. The advantage of a serial communications network is that its single common thread runs throughout the plant floor, replacing large, hard-wired umbilicals that are costly both to install and maintain. The overall advantages are well documented in many industrial applications. See **auxiliary equipment; microprocessor control; plant control; sensor.**

control, automatic A machine operating mode in which the equipment continues production output and line equipment operates in a feedback mode to continuously control dimensions, or until a fault develops. See **automation.**

control band, dead The range through which an input can be varied without initiating response.

control, blow-molding parison See **blow molding, extruder parison programmed-control.**

control, cascade A control method that uses the output of one controller to control, or feed, another.

control, change The activities that deal with product changes from the proposal to the implementation stages. The change control encompasses areas of raw materials, software, devices, processes, labeling and packaging, inspection, and so on. Change-control problems affect different plants such as being one of the top violations for medical-device quality system regulation (QSR). Therefore, device manufacturers must implement a procedure for managing changes in a product or in the manufacturing processes. Each manufacturer needs to find a model that complies with QSR and is suitable for its product and company, making appropriate adjustments as experience reveals new or better ways of handling changes. As with other similar situations, the start-up costs of such a project may seem high, but they should be weighed against the long-term benefits of improving efficiency and reducing the likelihood of recalls or lawsuits. See **quality system regulation.**

control chart See **statistical quality control.**

control, closed-loop A system that is used with a microprocessor to control a machine's line from start to the finished product. A controller compares input signals with set inputs; corrections are made when required. The system feeds back information such as dimensions to adjust line speed and to correct for dimension shifts. See **control, open-loop; injection-molding process control; motion-control system; servo control.**

control data See **fabricating, asynchronous.**

control, derivative A control mode in which there is a continuous linear relationship between controller output and the derivative of error signal.

control drive, optimized Virtually all new converting machines are electronically line shafted or designed as individually powered sections that are then precisely synchronized by digital control. With performance of these "shaftless" machines, electronic control is quickly forging the demise of the mechanical line shaft. Electronic line shafting sectionalizes the machine into separate sections, each powered by its own high-performance digital servo drive. A master control electronically synchronizes all machine operations, communicating in real time with each section's drive motor over a single fiber-optic cable. This shaftless design eliminates mechanical inaccuracies and provides for electronic registration with minimal loss of product during start-up. Trial-and-error mechanical adjustments are replaced with highly precise push-button electronic control. See **computer digital speed controller; drive motor control; fabricating process type; machining; printing; servo control; servo-control-drive reliability; temperature proportional-integral-derivative control algorithm.**

control, electronic logic A method that permits complex timing and sequencing functions in different processing equipment to be programmed and controlled.

control element, final The device that directly changes the value of the manipulated variable of a control loop.

control, feedback An action in which a measured variable is compared with the reference value to produce an actuating error signal, which is acted on to attempt to reduce the error.

control, feed-forward System in which corrective action is based on the measurement of disturbance inputs into the process.

control, front end See **control, open-loop.**

control, fuzzy-logic (FLC) A control method that avoids overshooting process limits and dramatically improves the speed of response to process upsets. These controllers accomplish both goals simultaneously, rather than trading one against another as done with proportional-integral-derivative (PID) control. However, not all FLCs are equal, and FLCs are sometimes switched off so that a traditional PID control takes over. FLC has been used to control many conveniences of modern life (from elevators to dishwashers) and more recently to control industrial processes such as temperature and pressure. See **process control; temperature proportional-integral-derivative control algorithm.**

control, human See **processing, intelligent.**

control, integral A control mode in which there is a continuous linear relationship between the integral of the error signal and the output signal of the controller.

controlled motion A means of low-friction precision linear motion that is provided by linear guides through an assortment of rails (round or profile), contact elements (rollers, ball bearings, or full-contact sleeves), and mounting configurations. Many types of guides exist, each engineered toward optimized performance in a specific range of applications. Therefore, various application criteria will effect linear guide incorporation. These criteria can be summarized as follows: dynamic load capacity, envelope size, mounting configurations, life, travel accuracy, rigidity, speed or acceleration, cost, and environmental considerations. The priority of these items will determine the appropriate linear guide for the application. See **accuracy; design lubricant, reduced-friction; design, motion-control, mechanical and electronic effects; motion-control system; repeatability.**

controlled-release delivery system See **biodegradable waste; coating, microencapsulation; drug application; medical-device packaging clarity.**

controller An instrumentation such as pressures, temperatures, or timers that is used to control and regulate the fabricating cycle. See **cybernetics; die temperature; mold temperature; potentiometer; process control; pyrometer; temperature measurement; temperature controller.**

controller, automatic set A technique that is used in modern controllers, compared with older proportional controllers, that permits more accurate control of temperature at set point even in the presence of lag time from remote locations.

controller, coordination The connecting of a group of controllers so that they may all be changed at the same time from a single point. For example, the extruder and haul-off may all be ramped up or down simultaneously.

controller, heating overshoot circuit. See **temperature controller, heating overshoot circuit.**

controller, multizone A microprocessor that monitors temperature, pressure, output rate, and so on signals from several sensors to achieve more reliable and efficient performance, either independently or coordinated.

controller, programmable logic See **motion-control system.**

controller safety See **programmable-controller safety.**

controller, temperature See **temperature controller rate term.**

control loop See **process control, control-loop.**

control, microprocessor See **processor, micro-, control.**

control mold parting line See **injection-molding process control parting line.**

control, motion See **motion-control system.**

control, nip pressure See **calendering, control nip pressure.**

control, open-loop Control of the fabrication process operation, from upstream through downstream equipment, where all controls are set by the operator and are not adjusted by feedback information. It will recognize a fault but not correct it. Also called *front-end control.* See **control, closed-loop.**

control plan A plan that lists step-by-step procedures describing how a specific operation will be conducted and followed. It includes many factors such as material handling and delivery rate, all equipment settings, processing controls, start-up, shutdown, and so on.

control, plant See **plant control.**
control plastic storage See **storage.**
control pressure See **injection-molding nozzle pressure control.**
control, quality See **quality control.**
control, production See **production-control system.**
control, proportional See **proportional control.**
control response The measurement of a variable and the corresponding control action. Pressure, temperature, and other controls combine with the instrument response loop to bring about precision in production. For example, due to the response lag in a pressure sensor, by the time an increase in pressure is transmitted to a control device the actual system pressure continues to change. The controller that receives this information then must process it and transmit an appropriate control response. This can usually take time. See **process control.**
control-response sensor A sensor that is designed to respond to a physical stimulus (temperature, pressure, motion, product gauging, product weight, etc.) and transmit a resulting signal for interpretation, measurement, or operating a control. A broad selection of sensors have extremely different sensitivities, capabilities, and repeatabilities. To select the correct sensor, the user should know something about how the different sensors work and which is used for what application. Not all sensors measure the same way. The three most common sensors used down-stream are nuclear, infrared, and caliper. Specialized types such as microwave, laser, X-ray, and ultrasonic sense different conditions for operating equipment (temperature, time, pressure, dimensions, output rate, etc.) and also sense color, smoothness, haze, gloss, moisture, dimensions, and many more. See **sensor.**
control, servo See **servo control.**
control, solid-state The type of control system that superseded relay control. It is based on electronic components that have no moving parts and yet can, for example, provide switching action.
control system See **process control.**
control system, manufacturing See **manufacturing execution system.**
control-system reliability Knowledge and understanding of the control system's expected behavior at startup, during processing, and at shutdown. The definition applies to both personal computer-based (PC-based) and programmable logic controller-based (PLC-based) systems with one exception. In a PLC-based system, control designers, as part of a supplier's quality-check responsibilities, confirm reliability. In a PC-based control system, users who take advantage of the key-system benefit of multivendor product integration shift responsibility for reliability from the supplier to themselves. Based on the extent of control-systems integration, the result can be a myriad of factors, known and unknown, that may contribute to reliability. Many factors contribute to system reliability, but the basic factors, risks, and suggestions include software issues, hardware issues, and both software and hardware. See **auxiliary equipment; reliability; risk.**
control, transducer-specification Understanding the accuracy of specifications on pressure transducers from different manufacturers. An ideal device would have an exactly linear relationship between pressure and output voltage. In reality, there will always be some deviations; this is referred to as being *nonlinearly*. The best straight line is fitted to the nonlinear curve. The deviation is quoted in the specifications and expressed as a percent of full scale. The nonlinear calibration curve is determined in ascending direction from zero to full rating. This pressure will be slightly different from the pressure measured in descending mode. This difference is termed *hysteresis;* it can be reduced via electrical circuits. See **hysteresis; transducer.**
control variable See **motion-control system; process control.**
control web stretching See **extruder-web stretching and tearing.**
convection The mass movement of particles arising from the movement of a fluid due to difference in a physical property such as density, temperature, and so on. It is energy transfer by moving or flowing of gas or liquid. Natural convection results from differences in density caused by temperature differences. Forced convection involves motion caused by pumps, blowers, and other mechanical devices. See **conduction, heat; coolant; heat; heater.**
convention, plastics See **Appendix D, Worldwide Plastics Industry Events.**
conversion See **Appendix B, Conversion Tables; weight-to-volume conversion.**
converter A device that converts stock material into finished products. An example is where the converter buys plastic film or sheeting in the form of roll stock and converts it into useful forms by slitting, die cutting, and heat sealing into bags for resale to the packaging industry. See **credit card.**
converting equipment Devices such as film winders, coaters, laminating, corona-treating rolls, and many more. They are usually identified as auxiliary equipment. See **auxiliary equipment; control drive optimized; fabricating process.**
conveying material See **material handling; conservation of matter, law of.**
conveying, pneumatic Bulk material handling and conveying. Almost any substance (pellets, granules, powders, etc.) can be conveyed pneumatically (air), increasing the efficiency of materials purchase, storage, and plant activities, such as fabricating machine hoppers. Velocity, which is defined as the rate of motion or speed, is the key to transporting materials. Pipeline conveyors are commonly referred to as *dilute-phase systems.* They convey a small volume of material by a large volume of air. The physics principles that play an important role in pneumatic conveying are gravity, pressure differential (force caused by a difference in pressure to initiate the movement of air and material), inertia, shear (between adjacent particles),

and elasticity (intrinsic tendency of a compressible gas to expand and flow from a high pressure to a low pressure). The basic laws of physics affecting fluid flow are the law of conservation of matter, law of conservation of energy, law of perfect gas properties, and laws based on Boyle's law, Gay Lussac's or Charles law, and the combined gas law. See **conservation of matter, law of; material handling; storage.**

conveyor A mechanical device that transports materials, products, and tools from one point to another, often continuously. The most important of these auxiliary equipment types are chain, belt, screw, and pipeline; nonmechanical types are gravity roller, bucket, and pneumatic. See **part handling.**

convexity See **shape, convexity.**

coolant A liquid or gas (air, etc.) that has the property of absorbing heat from its environment and transferring it efficiently away from its source. Coolants are used in different processes such as molds, chillers, and extruder cooling rolls. One of the most effective and low-cost coolants is water. Coolants operating below freezing incorporate antifreeze such as ethylene glycol. See **barrel cooling; chiller; convection; ethylene glycol; extruder cooling and take-off equipment; extruder line; extruder pipe, cooling-tank weir; extruder profile; extruder roll, cooling; mold cooling; mold cooling, flood; molding cooling, pulse; mold-cooling rate; Reynolds number; screw cooling; shrinkable fixture; temperature controller; thermal capacity; water, magnetic; water softening.**

cooking waste See **waste, pressure cooking.**

coolant, laminar flow A smooth, nonturbulent flow that is not desirable in a coolant system. See **coolant, turbulent-flow; melt flow, laminar; Reynolds number.**

coolant, turbulent-flow The opposite of laminar flow, where a fluid moves in all different directions, as is desired in mold-cooling channels. With turbulence, more heat will be removed since as the fluid on the inside surface of the channel is heated, that heated fluid moves away, subjecting a cooler fluid to rapid removal of more heat. With laminar flow, the fluid-heat build-up on the wall acts as an insulator so that inside laminar flow is an inefficient heat remover. See **melt flow, laminar; Reynolds number.**

cooling, chilled-water A hot/cold system that is used for central chilled-water systems, whether air or water cooled. This type of system incorporates a dual-compartment reservoir with dedicated process and chiller recirculation pumps. For cooling below the freezing point, antifreeze, such as ethylene glycol, is included in the water. See **ethylene glycol.**

cooling ring, venturi A unit used to cool or stabilize shaped melt, such as a film, by using a primary air stream to draw additional room air by the venturi effect and improve cooling. See **extruded-blown film air ring; venturi.**

cooling, super- The rapid cooling of a normally crystalline plastic through its crystallization temperature, so that it does not get a chance to crystallize, and it remains in the amorphous state. See **saturation, super-.**

cooling tower A method of cooling materials. Towers are more efficient when dual pumping systems are used with towers that utilize pressure sensitive nozzles for square spray patterns or towers equipped with rotating spray guns. These types do not perform well in single-pump systems due to inevitable changes in available water pressure at the tower inlets. With two or more chiller systems, consider butterfly valves installed between each unit and a pressure gauge installed between each valve and the inlet connection. This will properly balance recirculation flows through the heat-transfer equipment.

cooling trough/tank Usually a closed trough, filled with water, with or without sizing plates or a vacuum system around the extruded part (pipe, tube, rod, profile, etc.) being cooled.

cooperage The manufacture of barrels. Barrels formerly were made only of wood but now also are made of plastics such as blow-molded polyethylene plastic or reinforced thermoset plastics.

Coor's beer bottle During the mid-1950s, Coor's Beer Company in Colorado almost used commercially stretched, injection blow-molded bottles. It would have used the blow-molding injection with rotation process. Unfortunately, it was using acrylonitrile-styrene plastic (AN-styrene from Barex plastic from Sohia of BP Chemical International) (DVR project), which was banned by the FDA. Many years later it was approved for use. See **acrylonitrile-styrene plastic; blow molding, injection-with-rotation; blow molding, stretched; Coca-Cola bottle.**

coordinate measuring machine See **machine, coordinate measuring.**

copal A group of fossil plastics still used to some extent in varnishes and lacquers. They are insoluble in oils and water. The most important types are Congo, kauri, and manila. See **lacquer; varnish.**

copolyester plastic See **polyester plastic.**

copolyester elastomer (COPE) A material that was developed to replace rubber and thermoplastic elastomers and some high-performance engineering TPs. They are generally tougher than polyurethanes. In general, the main features of these semicrystalline TPs are wide temperature flexibility range, impact strength, chemical and weathering resistance, tear resistance, and abrasion resistance. They are random block copolymers consisting of rigid polyester blocks as the hard or stiff phase and flexible polyether or polyester blocks as the soft or rubbery phase.

copolymer A long-chain molecule formed by the reaction of two or more dissimilar monomers (bipolymer, terpolymer, quadripolymer, etc.). The final properties of a copolymer depend on the percentage of each monomer, the properties of each, and their arrangement along the chain. See **butadiene; chemical composition and properties of plastic; interpenetrating network; molecular structure; polymer.**

copolymer, alternating A pattern in which each repeating unit is joined to another repeating unit in the polymer chain (A-B-A-B-A-).

copolymer, azeotropic A copolymer in which the relative numbers of the different kinds of units (mers) are the same as in the mixture of monomers from which it was obtained.

copolymer B A repeating unit in a copolymer chain. It is an essentially linear copolymer consisting of a small number of repeated sequences of polymeric segments of different chemical structure.

copolymer, block Essentially a linear polymer in which there are repeated sequences of polymeric segments of different chemical structure. The polymeric chains are composed of shorter homopolymeric chains that are linked together. These blocks can be either regularly alternating or random. Thus, an essentially linear copolymer consists of a smaller number of repeated sequences of polymeric segments having different chemical structures. See **amorphous domain; copolyester elastomer; designing with plastic tailor-made models; material, microphase structure; polymer, block.**

copolymer, comonomer See **comonomer.**

copolymer, graft A high polymer, the molecules of which consist of two or more polymeric parts, of different compositions, chemically united together. A graft copolymer may be produced, for example, by polymerization of a given kind of monomer, with subsequent polymerization of another kind of monomer, on to the product of the first polymerization. This union would also produce a graft polymer. See **designing with plastic tailor-made models; material, microphase structure; polymer, graft.**

copolymer halogenated See **halogenation.**

copolymerization See **polymerization, co-.**

copolymer, random An alternating segment of two monomeric units of random lengths, including single molecules. They usually result from the copolymerization of two monomers in the presence of a free-radical initiator.

copolymer type See **interpenetrating network.**

copper (Cu) A material that provides good electrical and thermal conductivity, atmospheric corrosion resistance, ease of forming, and color. Copper and its alloys have rather low strength-to-weight ratios and low strengths at elevated temperature. Some alloys are susceptible to stress-corrosion cracking unless they are stress relieved. Use with plastics include insulated wire coatings, electroplating coatings, catalysts, antifouling plastic paints, beryllium-copper alloys for fast heat transfer in molds and dies, whiskers used in thermal and electrical RPs, and lacquer coatings. Regarding coatings, to retain its original alloy color without darkening, a protective coating is applied, such as an acrylic with benzotriazole. See **constantin; die material; electric; mold material.**

copper-clad laminate See **laminate, copper-clad.**

copper molding See **injection-molding nonplastic.**

copyright See **legal matter: copyright.**

coral Skeletons of the coral polyps found in the warmer oceans and consisting mainly of calcium carbonate with ferric oxide. It is used as filler. See **filler.**

cord See **wood cord.**

cordage All types of threads, twine, and rope produced by twisting fibers together. See **roving.**

core **1.** The central member of an assembly. See **blowmolding extruder core. 2.** The central member of a sandwich construction. See **design, sandwich-construction; sandwich core material. 3.** The male element in a mold or die that produces a hole or recess in a product. **4.** Parts of a complex mold that has undercuts. See **mold core. 5.** A channel in a mold for circulation of a heat transfer media. See **mold cooling; mold heating. 6.** In extruded blow molding, the part of the extruder die that controls the inside dimension of the parison. See **die. 7.** A core is used in wrapping film, fabric, and so on.

core, fluted An integrally woven reinforcement material consisting of ribs between two skins in a mixed sandwich construction. See **sandwich core material.**

core, honeycomb or foam Low-density, honeycomb, or cellular/foam material (plastic, reinforced plastic, aluminum, paper, etc.). Using different processing methods, the honeycomb is formed into hexagonal-shaped cells, resembling natural honeycomb, that are used as a core in sandwich construction where they contribute toward greater strength and rigidity. One processing technique is to have layers of flat sheets or films that basically have strips of adhesives applied. After curing in a flat press, the sheets or films are mechanically expanded to form honeycomb-constructed cores. Foam cores can be made from flat foamed slabs or sheets or can be foamed in-place between surface materials. See **sandwich-core material; foam.**

core molding See **soluble-core molding.**

core pin See **mold-core pin.**

Corfam DuPont's trade name for a tough, leatherlike, nonwoven sheet of polyurethane plastic fibers.

Corian DuPont's trade name for a marblelike material made from mineral filled acrylic cast-sheet. This solid material can be cut and shaped like hardwood. In a kitchen and bathroom, it has the beauty of expensive natural stone materials but is far more practical. It resist stains, impact, water damage, and fading caused by exposure to sunlight. Superficial cuts and scratches are easily removed. See **building and construction market.**

coring **1.** The removal of excess material from the cross-section of a molded part to attain a more uniform wall thickness. **2.** A method of sizing and shaping a blownbottle opening by appropriate tools. **3.** A variable composition between the center and outside of a unit of structure. See **machining.**

cork A form of cellulose comprising the light outer bark of the tree known as *Quercus suber*. It grows naturally in Europe and northern Africa and has been cultivated in the southwest United States. Its special properties are extreme lightness, relative imperviousness to water, resilient structure, and low rate of heat transfer. It is used in bottle stoppers, insulation, gaskets, and as the core in sandwich construction. See **bottle stopper.**

corkwood See **wood, balsa.**

cornering coefficient See **coefficient of cornering.**

corona See **electrical corona-discharge treatment; plasma treatment.**

corrosion Chemical erosion by motionless or moving parts. See **mold storage; phosphorous-base flame retardant; pipe, water deterioration; scale.**

corrosion, passivation The condition in which a normal corrosion is impeded by an absorbed surface film on an electrode. See **electrode.**

corrosion resistance The ability of a material to withstand contact with ambient natural factors or those of a particular artificially created atmosphere without degradation or change in properties. Since plastics (not containing metallic additives) are not subjected to electrolytic corrosion, they are widely used where this property is required alone as a product or as coatings and linings for material subjected to corrosion such as in a chemical, water-filtration, or mold and die plant. See **coating, steel-rod; concrete, reinforced; erosion; mold-cavity coating; screw coating; stress corrosion; zirconium.**

corrugated See **design, corrugated.**

corrugated tubing See **tube, collapsible squeeze.**

cosmetic market The cosmetic industry has made extensive use of many different plastics to meet stringent safety requirements, including those of the U.S. Food and Drug Administration. See **aesthetic; market; marking.**

cosmetic reinforcement See **alumina trihydrate.**

cosmetic specification, molded See **molded-part cosmetics.**

COSMIC software NASA's software catalog, via the University of Georgia, Computer Software Management and Information Center. It has over 1,300 programs, including programs on management procedures, thermodynamics, structural mechanics, heat transfer, fluid flow, and so on. See **computer software.**

cost The price that is needed to produce products, based on categories such as materials and hardware, method of purchasing, processing method, additives used, and manufacturing costs. Some plastics are low-cost, and others more expensive. It is usually best to compare materials based on volume rather than weight used. Plastics, low-cost processing is included when evaluating the cost of a product to be fabricated. See **economic efficiency and profitability; economic evaluation reliability; fabricating process type; plastic material type; process control, computer; profit; profitability study; quality control.**

cost analysis The economic evaluation that focuses on the costs of any intervention and does not consider outcomes.

cost analysis, least- A calculation of order quantity or production lot size that balances the inventory carrying costs against the ordering costs. See **A-B-C analysis.**

cost and economic growth See **gross domestic product.**

cost and marketing See **World of Plastics Reviews: Making Marketing Work.**

cost and molecular weight (MW) High-molecular-weight plastics are more expensive to produce and process; they generally require more highly purified monomers. In many additional polymerization reactions, HMW requires a lower polymerization temperature, often involving costly refrigeration and longer polymerization time. Occasionally, low-molecular-weight plastic is more costly to produce for various reasons. For example, in coordination polymerization of polyolefins, it is often easy to reach extremely HMWs, and much more difficult at controlled LMW required temperatures, which create higher vinyl chloride monomer pressures. When a specific MW distribution is required, this may also involve additional manufacturing costs. See **molecular weight.**

cost-benefit analysis (CBA) The economic analysis, such as with research programs, in which both the inputs to produce the intervention (or costs) and its consequences or benefits are expressed in monetary terms of net savings or a benefit-cost ratio. A positive net saving or a benefit-cost ratio greater than one indicates the intervention saves money. See **cost analysis; cost-effectiveness analysis; profit and technology; research and development.**

cost, capacity differential The difference between the hourly production cost based on expected volume and the hourly cost based on practical capacity volume.

cost, capital-equipment See **capital-equipment investment; capital-equipment investment tax credit.**

cost, carrying The amount of expense incurred in holding inventory. It is usually expressed as a percent of the inventory value. It includes the costs of storage facilities (air conditioning, fire proofing), insurance, handling, and financing. When inventory is not moving, it can be very expensive to hold. See **production performance.**

cost, compensating balance An average daily balance of a bank account, the earnings of which are sufficient to defray the cost of the bank's handling of the transactions for the account. It represents a form of security, or collateral, against loaned funds.

cost, contract See **government contract directory; legal matter: product liability law.**

cost contribution The portion of the net sale dollar left after all variable costs have been deducted.

cost conversion The cost of direct labor and overhead required to make the finished product. See **specific gravity conversion.**

cost, corollary savings Economic advantages realized because of a reduction in indirect costs.

cost, decorating See **decorating; film decorating; texturizing.**

cost, demurrage A fee imposed on shippers of plastics and chemicals by the railroads for freight cars at loading docks for more than a given period of time, usually 24 h.

cost, direct and indirect As the controllable cost of prevention and appraisal increases, the uncontrollable cost of internal and external failure decreases. At some point the cost of prevention and appraising defective products exceeds the cost of correcting for the product failure. This point is the optimum operating quality cost.

Indirect quality costs can be divided into three categories: customer-incurred quality costs, customer-dissatisfaction quality costs, and loss-of-reputation costs. These intangible, indirect quality costs are difficult to measure but do effect the total quality-cost curve. This influence is apparent when the indirect quality costs are added to the direct cost curve. When the optimum point increases, it indicates the need for a lower product-defect level. A lower product-defect level can be obtained by increasing the prevention and appraisal costs, which subsequently lowers the external failure costs. A lower external failure has a desirable influence on the direct costs. The measurement of the actual indirect costs may be impossible, but knowing that these costs exist and their relationship to the direct costs can aid in their control.

cost effectiveness Minimizing costs is generally an overriding goal in any application, whether a process is being selected for a new product or opportunities are being evaluated for replacing existing materials. The major elements of cost are equipment, material, and inefficiencies such as scrap, repairs, waste, and machine downtime costs to granulate, handle, and slow down the line. Each of these elements must be evaluated before determining the most cost-effective approach. See **material handling, automatic; technical cost modeling.**

cost-effectiveness analysis (CEA) The economic analysis in which the consequences or effects of intervention are expressed in improvements such as fabricating successful products, years of service, and so on. See **cost-benefit analysis.**

cost-effective training Proper training of employees to help (and even eliminate) variable costs. In addition to other forms of training, such as shop-floor training, seminars, video, and reading, implementing an interactive in-house training program becomes an important cost-effective form of educating the workforce. Interactive training has proved to be the best way to provide employees with the skills and knowledge that ultimately create a more confident and productive workforce. See **education; training.**

cost, energy Cost savings via energy conservation can be considered from the viewpoints of machine operation, the plastic material, and the finished product. Fabricating machines are usually energy intensive, so energy reduction begins with the purchase of any equipment in the line. See **energy; energy and bottles; energy and plastic; energy consumption; energy efficiency.**

cost estimating A critical aspect of custom fabrication that tells customers what can be done at what cost and that is often practiced with little logic. Fewer than 10 estimates in 100 produce a successful bid. Some estimates may not consider scrap, coloring, setup time with trial and error, and so on. Some estimates are simple creations such as determining the part weight, cost of plastic, and processing time; scribbling down some numbers; and adding a fudge factor (possibly a little prayer). Some companies do not even have their own standard forms whereby they could develop some useful history. Because plastic processing is a highly competitive industry, quotes should be prepared only where a payoff has a possibility to occur. See **technical cost modeling.**

cost, fair market value See **legal matter: fair market value.**

cost, fixed A cost that will not vary markedly within the normal range of operations.

cost, free trade See **legal matter: free trade.**

cost freight car retention See **cost, demurrage.**

cost, hidden See **technology assessment.**

cost, inventory A group of costs related to inventory. It includes item costs, ordering costs, carrying costs, and stock-out costs.

cost, item The actual invoice and inbound freight costs of a purchased item and the variable manufacturing costs (material, direct labor, and variable manufacturing overhead) of a product fabricated.

cost, load The amount of work expressed in hours, kg (lb), or even dollar value of an order.

cost, medical See **medical cost-of-illness study; medical-device packaging clarity; medical material and the environment.**

cost-minimization analysis (CMA) An analysis that shows that two alternatives have equivalent effectiveness so that only their costs need to be compared to identify the most economically desirable alternative. See **economic efficiency and profitability.**

cost modeling See **technical cost modeling.**

cost, mold See **legal matter: mold contractional obligation; mold cost.**

cost, ordering For purchased items, the total cost to place a purchase order, receive items, and pay the invoice. For manufacturing items, it includes the cost of preparing the production papers, scheduling the work, preproduction mold and tool maintenance, and set-up.

cost-overhead rate A manufacturing overhead hourly rate based on the practical capacity volume of an operation. See **machine-hour rate.**

cost per volume of plastic To determine the cost per volume of plastic material, multiply cost per pound with specific gravity and in turn multiply with 0.03163; thus cost/in.^{3} = cost/lb × s.g. × 0.03163. See **specific gravity; volume-to-weight conversion.**

cost, plant See **designing plant layout via computer; production data acquisition.**

cost, product The total of all costs required to produce a product. In a production line that has a relatively long run, the cost for equipment in relationship to producing the product including its financial amortization, could be about 5%. Plastic material cost could be as high as 80% for high-volume production. The other costs include power, water, labor, overhead, and taxes. With precision, short runs, costs could be equipment at 20 to 30% and material at 45 to 50%. Equipment that costs less may produce less profit than more expensive equipment. Of course the reverse is possibly true. See **mold cost; product update; test, product weight.**

cost, recycling See **material buy-back; recycling cost; recycling limitations; recycling method, economic evaluation of.**

cost reduction The following practices help to reduce costs: (1) strive for the simplest shape and form; (2) combine parts into single extrusions, use more than one die to extrude products, or use multiple die heads and openings; (3) make gradual changes in thickness to reduce frozen stress; (4) where bends occur, use maximum permissible radii; (5) purchase plastic material as economically as possible; (6) keep customer tolerance as liberal as possible, but once in production aim for tighter tolerances to save material costs and also probably reduce production costs. See **economical control of equipment; extender; injection molding, gas-assist; processor and competition; technical cost modeling.**

cost, supplier See **monitoring customers and suppliers.**

cost target The production flexibility of the plastics fabrication processes is often the single most important economic factor in producing a product. The product's size, shape, complexity, strength, and orientation can be primary determinants but are not impossible to produce. Thus, processing takes on the task of doing the impossible at the lowest cost. Economics can be improved by targeting various factors: (1) reduction in the use of material by minimizing tolerances, (2) improvement in product quality in terms of strength and/or other mechanical-physical characteristics, (3) reduction in setting-up times of start-up aids and automation systems, and (4) savings in electricity consumption by the optimization of the plasticizing and the use of efficient heating and cooling.

cost, technical modeling See **technical cost modeling.**

cost, transportation See **truck and plastic.**

cost-utility analysis (CUA) The economic analysis in which the consequences are expressed as the utility or quality of the outcome. See **quality.**

cost variable A cost variation may be due to one or more of the following factors: (1) improper or unattainable performance requirements, (2) improper plastic selection, (3) improper in-line and off-line hardware and control selections, (4) improper selection of the complete line, (5) improper collection or handling at the end of the line, and (6) improper setup for testing, quality control, and troubleshooting.

cotton The fibers of plants of various species of Gossypium. Cotton is used in the plastics industry to produce products such as cellulose derivative plastics, as a filler in molding compounds (cotton flock filler), in reinforced laminated plastic, and so on. See **fabric, canvas; rayon.**

cotton linter See **fiber linter.**

coulomb See **electrical coulomb.**

coumarin See **optical brightener agent.**

coumarone-indene plastic A coal-tar thermoplastic that is produced by heating a mixture of coumarone and indene with sulphuric acid. It is pale yellow to dark brown in color and soluble in hydrocarbon solvents. These plastics have no commercial applications when used alone. They are used primarily as processing aids, extenders, and plasticizers with other plastics such as in asphalt tile.

council, solid-waste See **waste, solid, council.**

count See **fabric count; softener; yarn count.**

counterflow injection molding See **injection-molding counterflow.**

counterpressure molding See **injection molding, foamed-gas counterpressure.**

counterrotating screw See **extruder, multiple-screw.**

countersink An internal chamfer.

coupling agent See **fiberglass binder/sizing coupling agent; reinforced plastic coupling agent; titanate coupling agent.**

coupon See **test coupon.**

covalent bonding A bond in which two electrons are shared by the two atoms of either the same or different elements. See **atom, electrovalent bond; molecular structure configuration.**

covering, roll See **roll covering.**

cowoven fabric See **fabric, cowoven.**

C/R See **screw compression ratio.**

CR-39 plastic See **allyl diglycol carbonate plastic.**

crack A surface defect. Atmospheric cracks appear on the surface of certain plastics and are caused by weathering. Cyclic deformation (bending) usually results in perpendicular cracks caused by the strain in the plastics when exposed to ozone. If cracks extend through the plastic, they could represent a fracture. See **crazing; environmental stress cracking; fracture; orientation, accidental; reinforced-plastic hairline craze; reinforced-plastic microcracking; reinforced-plastic pultrusion crack; stress crack; test analysis, micromechanical.**

crack damage tolerance See **damage tolerance.**

crack growth Crack-growth behavior can be analyzed using fracture mechanics so that fracture toughness can prevent fracture. Fracture is a crack-dominated failure mode. For fracture to occur, a crack must somehow be created, then initiate, and finally propagate. The prevention of any of these events will prevent fracture. Cracks can be considered elastic discontinuities that can come from a variety of sources, such as internal voids or dirt, surface scratch, embrittlement, or weld line. Cracks can be the consequences of faulty design, poor processing or poor handling of raw material, assuming the material arrived clean. See **design failure theory, Griffith; fracture; test, crack growth.**

crack growth rate The rate of propagation of a crack through a material due to static or dynamic applied load. See **tolerance, damage.**

crack, hairline A small fissure in plastic, such as coatings, often caused by uneven cooling or curing during processing. See **crazing; reinforced plastic hairline craze.**

cracking 1. A refining process involving decomposition and molecular recombinations of organic compounds, especially hydrocarbons obtained by means of heat, to form molecules suitable for monomers, using petrochemicals, gas, and so on. It can operate at 400 to 600°C (752 to 1,112°F) and at pressures slightly above atmospheric to make waxy oligomeric liquids suitable for further catalytic cracking-gases formed fuel process. See **oil, cracking; plastic raw material to product; recycling, chemical. 2.** See **crack; fatigue; phosphorous-base flame retardant.**

crack initiation or propagation See **fatigue.**

cratering See **coating cratering; powder coating.**

crazing Fine, thin, tiny cracks that may extend in an unreinforced or reinforced plastic network on or under the surface or through a layer of the plastic material. Also called *hairline craze.* See **blush; cracking; phosphorous-base flame retardant; plastic product failure; stress crack; stress whitening; test analysis, micromechanical.**

crazy putty See **putty, bouncing.**

credit card A printed and laminated piece of plastic core stock that is usually rigid PVC. Most are die cut from sheets 20 to 23 in. (50 to 58 cm) wide by 26 to 30 in. (66 to 76 cm) long. Secure card manufacturers generally produce their cards in one of two ways: (1) by applying a 1.8 to 2.0 mil (0.045 to 0.051 mm) thick PVC film laminated to both sides of a 26.0 to 26.5 mil·(0.66 to 0.67 mm) usually homopolymer sheets or (2) by using the split-core method where two 13.5 mil (0.34 mm) thick copolymer sheets are joined through a heat-pressure lamination process followed with a film overlay that is thinner than that used in the solid core.

Thickness control is important otherwise problems will develop with card embossing equipment and the magnetic-stripe-reading machines. Other considerations that influence calendering sheet include ink adhesion, flex capabilities, cleanliness, and embossed-characteristic height retention. Secure cards tend to be made from PVC copolymers, while others with less stringent performance demands often are made from homopolymers. The life expectancy of cards is about three years. New plastic compounds continue to be evaluated to extend life with cost reductions. See **business card, electronic; calender; card, smart; converter.**

creel See **fiber creel.**

creep The time-dependent increase in strain in material that occurs under stress. Creep at room temperature is sometimes called *cold flow.* It is the change in dimensions of a plastic under a given stress, load, and temperature over a period of time, not including the initial instantaneous elastic deformation. The following factors should be considered when reviewing creep properties and behavior: (1) predictions can be made about creep behavior based on creep and relaxation data, (2) less pronounced curvature appears when creep and relaxation are plotted log-log to facilitate their extrapolations, and (3) particulate fillers provide better creep resistance than unfilled plastics but are less effective than fibrous reinforcements. During the twentieth century plastic products have been successfully designed for long term creep performance based on laboratory testing and analyzing data. See **deformation under load; designing with creep data; electrical creepage; flow, cold; production performance; rupture time; viscoelastic creep.**

creep isometric and isochronous graph Creep curves are a common method of displaying the interdependence of stress-strain-time. However, other methods may be useful in particular applications such as isometric and isochronous graphs. The isometric graph provides an indication of the relaxation of stress in the material when the strain is kept constant. It also provides the time-dependent variation of modulus. With the isochronous graph a time is constant through the creep section relating to stress versus strain. Other information is obtained and is useful in design and so on.

creep loading The creep behavior of plastics is usually reported at the level of the applied stress being constant. However, in service the material may be subjected to a complex pattern of loading and unloading cycles. In these cases it is useful to develop intermittent loading data. With high-performance plastics dynamic loads such as creep, impact, and related issues are important considerations in many products. These materials' behaviors are influenced by many factors that include temperature and time. If a product fails in the performance of its normal long-time function, it is usually caused by one of two factors—excessive deformation or fracture.

creep modulus, apparent The concept of apparent modulus is a convenient method of expressing creep because it takes into account initial strain for an applied stress plus the deformation or strain that occurs with time. Because parts tend to deform in time at a decreasing rate, the acceptable strain based on service life of the part must be determined. The shorter the duration of load, the higher the apparent modulus and the higher the allowable stress. Also called *viscous modulus.* See **modulus, apparent.**

creep rate The slope of the creep-time curve at a given time; deflection with time under a given static load. See **deformation under load; flow, cold.**

creep recovery The time-dependent decrease in strain following the removal of the force.

creep relaxation A transient stress-strain condition in which the strain increases concurrently with the decay of stress. See **relaxation.**

creep rupture strength The stress that causes fracture in a creep test specimen at a given time, in a specified constant environment. Also called *stress-rupture strength.* See **rupture time.**

creep strain, initial The strain produced by given load conditions before creep occurs. See **strain.**

creep strength The stress that causes a given creep in a creep test at a given time in a specific constant environment. See **strength; stress.**

creep, zero time See **zero time.**

cresol A series of compounds, all of which are soluble in ordinary organic solvents. It is used in the production of plastics such as phenolic. See **phenolic plastic.**

criminal justice and plastic See **legal matter: forensic science and plastic.**

crimp **1.** See **fiber crimp. 2.** The corrugations on a part to lock them in place.

cristobalite See **fiber, silica.**

crocidolite An asbestos fiber that occasionally is used as a filler in plastics. Fiber diameter is about 100 nm and bundle lengths about 20 mm. Important properties include being acid resistance, tensile strength is 3.5 GPa and modulus is 175 GPa, etc. The toxic hazard associated with asbestos requires careful handling and use. See **asbestos.**

crocking The removal of a dye or pigment from the surface of a paint or textile by rubbing or attrition.

cross breaking strength See **flexural strength.**

crosshead See **die, crosshead.**

cross laminated See **directional property, crosswise; laminate.**

cross-link With thermoset plastics and certain thermoplastics, the setting up of chemical links between the occurring molecular chains. When extensive, as in most thermoset plastics, cross-linking makes an infusible supermolecule of all the chains. The plastic formed usually cannot be remelted because the bonds are too strong. The greater the degree of cross-linking, the greater the rigidity of the plastic, the less it is soluble, and the less it responds to remelting. See **cross-linking; molecular structure.**

cross-linked density See **polymer cross-linked density.**

cross-linked network parameter A measure of the cross-link density of a plastic; the molecular weight of the primary chain segment between the cross-links. It is readily determined only in lightly cross-linked elastomers either by equilibrium swelling measurements or from measurements of stress-strain behavior.

cross-linked polyethylene plastic When subjected to cross-linking, conventional thermoplastic polyethylene becomes a thermoset polyethylene plastic with different or improved properties. See **extruder wire and cable cross-linking PE without peroxide; extruded wire and cable cross-linking PE with peroxide; polyethylene plastic.**

cross-linking The setting up of chemical links between the molecular chains of polymers. It is the principal difference between thermoplastics and thermosets plastics. During curing or hardening of TSs the cross-links are formed between adjacent molecules producing a complex, interconnected network that can be related to its viscosity and performance. These cross-bonds prevent the slippage of individual chains, thus preventing plastic flow under the addition of heat. If excessive heat is applied, degradation rather than melting will occur. Certain TPs can be converted to TSs providing improved properties. They can be cross-linked by different processes such as chemical and irradiation. PE is a popular plastic that is cross-linked; its abbreviation is *XLPE.* Cross-linking is an irreversible change that goes through a chemical reaction—that is, by condensation, ring closure, or addition. Cure is usually accomplished by the addition of curing (cross-linking) agents, with or without heat and pressure. Also called *cross-linking.* See **barrier plastic; cross-link; cure electron beam treatment; interpenetrating network; ionic bonding; vulcanized elastomer; zinc acetate.**

cross-linking, chemistry See **polymer chemistry terminology.**

cross-linking cryogenic See **bottle, cryogenically cooled filling; cryogenic.**

cross-linking density See **polymer cross-linked density.**

cross-linking network characteristic The accurate characterization of cross-linked polymer networks is among the more difficult tasks of polymer analysis. Yet cross-links have a major effect on physical and mechanical properties of the fabricated plastic products. Cross-linked materials are relatively difficult to handle by solution techniques due to limited solubility. Solution techniques can be used after a degradative process has been applied. Many of the characterization tests are based on mechanical properties such as stress-strain, tensile, compression, hardness, and other properties. See **hardness; modulus of elasticity; strength; stress-strain curve; tensile strength.**

cross-linking, radiation The interaction of electromagnetic radiation with plastics, which can lead to the formation of three-dimensional network molecular structures that generally improve the overall physical and chemical properties of the original substrate polymer. Network structures form under a wide variety of radiation conditions (ionizing or nonionizing radiation, photochemical or thermal chemical cure systems). In general, cross-linking and the related technologies involve four main variables: the type of radiation and source, the nature of the polymer structure to be irradiated and its response characteristics, the mechanisms or theories of reaction, and the chemical, physical, and mechanical properties of network formation. The most common radiation sources are cobalt 60, low- and high-energy electron accelerators, light energy (ultraviolet visible), infrared sources of energy, and plasmas or glow-discharge energy sources (microwave or radiofrequency range). See **extruder.**

cross-linking rubber See **vulcanizing agent; wire and cable.**

crosswise direction See **directional property, crosswise.**

crowfoot pattern See **fabric woven.**

crushing load See **load column crush.**

crush test See **test, container column crush.**

cryogenics **1.** The science of low temperature conditions. See **chemistry, cryo-; conductivity, super-; deflashing, cryogenic; material pulverizing; recycling, cryogenic.** **2.** The study of the behavior of material at temperatures below −200°C (−328°F). **3.** The use of liquified gases.
cryogenic bottle See **bottle, cryogenically cooled filling; deflashing, cryogenic; recycling, cryogenic.**
cryogenic property Properties at low temperatures. Thermal shock is a critical problem with certain plastics. As an example, fluoroplastics (also called *fluorocarbon plastics*) have shown superior resistance to embrittlement, and thermoplastic polyester films are useful in specialized problems with liquid hydrogen. In general, most plastics are twice as strong at cryogenic temperatures as at room temperature. As temperatures decrease, generally increases occur in strengths, modulus, and total thermal contraction. There is variable change in impact strength, adhesive shear strength, and coefficient of thermal conductivity. Decreases can occur in ductility, elongation, coefficient of expansion, and specific heat. See **fluoroplastic.**
cryogenic recycling See **recycling, cryogenic.**
cryogenic service Usually refers to temperatures below −100°C (173°K). See **temperature.**
Cryovac W. R. Grace & Co.'s trade name for a light, shrink film, transparent packaging material based on polyvinylidene chloride plastic. It is used especially for meats and other perishables.
crystal The normal form of the solid state of materials that form regular structures. Crystals have characteristic shapes and cleavage planes due to arrangement of their atoms, ions, or molecules that comprise a pattern called a *lattice*. See **allotropy; orientation, random; polarized light.**
crystal growth habit **1.** The characteristic mode of growth or occurrence of a crystal. **2.** The characteristic assemblage of forms (free faces) at crystallization leading to a usual appearance. See **nucleation, secondary.**
crystalline dislocation Any variation from perfect order or symmetry in a crystalline lattice.
crystalline growth See **transcrystalline growth.**
crystalline melting point The temperature of melting of the crystalline phase of a crystalline plastic. It is higher than the temperature of melting of the surrounding amorphous phase.
crystalline plastic The relatively regular repeating structure of thermoplastic molecules. Crystalline plastics are usually translucent or opaque and generally have higher softening points than the corresponding amorphous plastics. They can be made transparent with chemical modification. Partly crystalline plastics are often less brittle than amorphous plastics. Technically they are called *semicrystalline* since typically less than 80% of their content is crystalline; the remainder is amorphous. They tend to pack into orderly three-dimensional geometric symmetry, providing an arrangement of high density, sharp melting point (T_m), and directional properties. When molecules crystallize, their high degree of organization becomes a major factor in their overall structure. Thus properties depend on the percent of crystallinity and the size of the crystals present. See **amorphous plastic; amorphous plastic region; amorphous plastic scatter; annealing; birefringence; cooling, super-; deflection temperature under load versus crystallinity; glass transition temperature; heat capacity; heat profile; melt flow; melting temperature; mold cooling rate; molecular arrangement structure; morphology; orientation, random; plastic solidification; polarized light; spherulite; Staudinger, Hermann; stereospecific plastic; temperature and molecular bonding force; test, nondestructive carbon fiber reinforced plastic x-ray scanning; transparent.**
crystalline plastic and glass transition See **glass transition temperature and crystalline melting point.**
crystalline plastic and polarized light See **polarized light.**
crystalline plastic, annealed See **annealing.**
crystalline plastic lamella The basic morphological unit of a crystalline polymer, usually ribbonlike or platelike in shape. The ribbonlike are generally about 100 A (10 nm) thick, 1 µin (40 µin) long, and 0.1 µm (4 µin) wide. *Lamellae* is the plural of *lamella*. The average thickness of lamellae in a specimen (usually estimated from x-ray studies or electron microscopy) is 100 to 500 A (10 to 50 nm).
crystalline plastic relaxation With thermoplastics, a relaxation with its accompanying transition associated with the crystalline regions. The most important relaxation or the primary relaxation is melting. Certain secondary transitions are also sometimes observed, such as premelting.
crystalline plastic, transparent See **transparency improvement.**
crystalline, semi- A plastic that exhibits localized crystallinity. Thermoplastics are basically either semicrystalline or amorphous plastics. Generally the semicrystallines are called *crystalline plastics*. See **amorphous plastic; crystalline plastic lamella; semicrystalline plastic.**
crystalline solution See **deliquescence.**
crystalline region See **amorphous plastic region.**
crystallinity and load See **deflection temperature under load versus crystallinity.**
crystallinity and orientation Orientation of the crystalline axis with reference to some fixed direction, often the direction of deformation (machine direction). Intermolecular order refers to the geometric arrangement of adjacent molecules in the solid mass. See **directional property; orientation and crystallization.**
crystallinity and properties When molecules crystallize, this high degree of organization becomes a major factor in the overall plastic structure. In particular, the forces holding the plastic molecule into the crystalline lattice greatly restricts its mobility and thus affects most of its properties. Thus, most properties depend on the percentage of crystallinity and the size of the crystals present. See **amorphous plastic; biodegrading microorganisms.**

crystallinity versus temperature See **test, deflection temperature under load versus crystallinity.**
crystal, liquid An organic compound in an intermediate or mesomorphic state between solid and liquid.
crystallite The crystal present in a crystalline polymer. In contrast to nonpolymer, crystallites are so small that they can be observed only with an electron microscope. See **polariscope; transcrystalline growth.**
crystallization The formation of crystallites or groups of molecules in an orderly structure within the plastic as the plastic is cooled from its amorphous melt state to a temperature below its crystallization temperature. See **cold working; crystallization-induced stress; orientation and crystallization; polyethylene terephthalate plastic; water of hydration.**
crystallization and orientation See **orientation and crystallization.**
crystallization, degree of See **differential scanning calorimetry; x-ray spectroscopy.**
crystallization, first-order transition A change of state associated with crystallization, melting, or a change in crystal structure of a polymer.
crystallization, fractional The separation, by successive solutions and crystallizations, of different substances in a mixture.
crystallization habit **1.** The characteristic mode of growth or occurrence of a crystal. **2.** The characteristic assemblage of forms (free faces) at crystallization leading to a usual appearance.
crystallization, hydrothermal A procedure for growing single crystals within a heated aqueous solution.
crystallization-induced stress The production of crystals in a plastic by the action of stress, usually in the form of an elongation. It occurs in plastic fiber spinning, rubber elongation, and so on, resulting in improved properties. See **fiber processing, spinning; orientation; rubber.**
crystallization nucleating agent See **nucleating agent.**
crystallization, row nucleating See **fiber processing, spinning, row nucleation.**
crystallization, secondary A slow crystallization process that occurs after the main solidification process is complete. It often is associated with impure molecules. Also referred to as second order transition.
crystallography The study of the crystal formation of solids, including X-ray determination of lattice structures, crystal habit, shape, form, and defects of crystals. When applied to metals, this science is called *metallography.*
crystal orientation See **orientation, random.**
crystal plastic See **liquid crystal polymer or plastic; liquid crystal, lyotropic.**
crystal polymer, liquid See **liquid crystal polymer or plastic.**
crystal polystyrene plastic See **polystyrene plastic, crystal.**
crystal-pulling A method of growing single crystals by slowly pulling a "seed" crystal away from a molten pool.
crystal structure The orderly, repeating arrangement of atoms or molecules in a material. See **light microscopy; molecular structure.**
crystal, thermotropic liquid See **thermoforming, thermotropic liquid crystal in.**
crystal, zone fusion A procedure for growing single crystals by moving a molten zone along a rod of the material. See **zone.**
C-stage See **A-B-C stages; postforming.**
cull See **transfer molding cull.**
cullet In ancient glass manufacturing, the chunks of glass of varying sizes and colors that were furnished to artisans for shaping and finishing. Today, the term refers to fragments of scrap glass. See **glass filler.**
cupric oxide (CuO) Black, monoclinic crystals, insoluble in water. It is used in making fibers and ceramics, etc. Also called *copper oxide.* See **fiber processing.**
cuprous oxide (Cu_2O) An oxide of copper found in nature as cuprite and formed into copper by heat. Its major uses are as a pigment and as a fungicide. Also called *copper oxide.* See **biocide.**
cure To change the properties of a plastic material by chemical polycondensation or addition reactions. It generally refers to the process of hardening a plastic. More specifically, it refers to the changing of the physical properties of a material by chemical reactions usually by the action of heat (includes dielectric heat) and/or catalyst with or without pressure. It is the process of hardening or solidification involving cross-linking, oxidizing, or polymerization (addition or condensation). The term *curing,* even though it is applied to thermoset and thermoplastic materials, refers to a chemical reaction (cross-linking) or change that occurs during its processing cycle. This reaction occurs with TS plastics or TS elastomers as well as cross-linked TPs that become TSs. The TP materials go basically through a melting action. However, the more popular plastics at the beginning of the twentieth century (with about 90wt% of the market and principally the TS phenolic) were TSs, and the term *curing* was correctly used for TSs. Even with the advent of TPs early in the twentieth century (now over 90wt% of all plastics) the term continued to be used to indicate any plastic (TP or TS) that goes from a melt stage to a hardened stage. Also called *curing.* See **adhesive set; cross-linking; dielectric analysis; plastic; pot life; vulcanization.**
cure degree The degree of cure is the extent to which curing, or hardening, of a thermoset plastic has progressed. See **differential scanning calorimetry.**
cure, fast See **resorcinal-formaldehyde plastic.**
cure, ramping See **ramping.**
cure, step A cure that starts at lower temperature and is gradually brought up to the cure temperature. This action allows gasses to escape before solidification of the plastic, such as in curing of phenolic plastic. See **mold breathing.**
curie The official unit of radioactivity where Ci is defined as exactly 3.70×10^{10} disintegrations per second.

This decay rate is nearly equivalent to that exhibited by one g of radium in equilibrium with its disintegration products. A millicurie (mCi) is 0.001 curie.

curie point See **magnetized curie point.**

curing See **autoclave nitrogen atmosphere; cure; extruder wire and cable process, dry cure; inhibitor; prepreg volatile content; reinforced plastic resin transfer molding; test, Barcol hardness; test, scorch Mooney; thermoset plastic; vulcanization; welding, induction.**

curing, after- A continuation of the process of curing after the energy source has been removed.

curing agent The catalytic or reactive agent that causes cross-linking. Also called *hardener.* See **aerobic; cross-linking.**

curing agent, blocked A curing agent or hardener that has been rendered unreactive but can be reactivated as desired by physical or chemical means. Also called *hardener.*

curing agent, latent An agent that produces long-term stability at room temperature but rapid cure at elevated temperatures.

curing, dielectric A process of curing thermoset plastics by a high-frequency generator electric charge passing through it. The charge is produced from a high-frequency generator. See **dielectric; dielectrometry; heating, dielectric; thermoset plastic curing, dielectric monitoring.**

curing, hot-air-oven A process of curing favored for curing rubberized and elastomer fabrics, such as those used in footware and clothing. Dry heat produces a drier surface and eliminates the unsightly water marking that often occurs on products cured in open steam. However, hot air curing is more costly than steam because longer cure cycles are required due to poorer heat transfer.

curing, kick-over The curing of a thermoset plastic to the solid state. Also called *set-up cure.*

curing monitor A technique for overseeing curing. A popular one detects changes in the electrical properties or mobility of the plastic molecules during curing. It provides a controlled measure of cure. See **dielectric monitoring.**

curing oven A heated chamber designed to provide the heat necessary to effect the cure of a plastic product.

curing, post- In certain plastics, particularly thermoset plastics, the complete cure and ultimate mechanical properties or other performances that is attained only by exposure of the cured plastic product after demolding to higher temperatures, usually without pressure, than those of the cure or melt process. When volatiles exist, annealing can release the volatiles during post curing.

curing, pre- **1.** The full or partial setting of a plastic before the complete cure, during which time the precured plastic can be positioned in a particular process. An example is precuring a plastic for an adhesive bond prior to clamping the joint or prior to applying pressure. **2.** A defective thermoset molding material when the material has begun to harden before the application of heat and pressure and will therefore not soften or flow properly in the mold.

curing, step A process of curing that is started at lower temperatures and gradually brought up to the cure temperature. This action allows gasses to escape before solidification of certain thermoset plastics, as in the curing of phenolic plastic.

curing stress The residual internal stress produced during the curing cycle of reinforced plastic structures. Normally these stresses originate when different components of a lay-up have different thermal coefficients of expansion. Stresses can also occur when curing thermoplastic—that is, going through a heat melting to cooling cycle. See **thermoplastic.**

curing temperature The temperature at which the plastic product will become cured.

curing, under- A state of thermoset curing or vulcanization between the onset of reaction and the state of optimum cure. It is an undesirable condition of a fabricated part due to little time, temperature, or pressure for adequate hardening of a part.

curling **1.** A condition in which blow-molded parison curls upward and outward, sticking to the outer face of the die ring. Balancing the temperatures of the die and mandrel will usually relieve this problem. See **blow molding. 2.** The warping or distortion of an adhesive bonded assembly due to the introduction of moisture or solvents into the adherend surfaces and due to the unequal contraction and expansion properties of the adherent surface. See **adherend; adhesive.**

curtain coating See **coating, curtain.**

curtaining See **blow molding, extruder curtaining.**

curve diagram See **directional property, abscissas; directional property, ordinate.**

cushion **1.** In extrusion blow molding, the slowing down of the molds just prior to their coming together. **2.** In injection molding, the packing of the mold cavity. See **injection-molding melt cushion. 3.** In other processes, such as reinforced plastic processing, a delay action just prior to the plastic solidifying to ensure even melt flow, elimination of air and other gas contamination, and so on. See **mold-filling hesitation. 4.** See **packing factor.**

cushioning material A material such as plastic foam that is used to isolate or reduce the effect of external applied shock or vibration forces.

customer See **fabricating outsourcing; fabricating, world-class; monitoring customers and suppliers.** See **Making Marketing Work.**

customer reciprocity The practice of giving preference to certain vendors who are also customers of the buyer's company.

custom processor See **processor, custom.**

custom product A product that has been tailored to a particular customer's specification.

cut, fly An operation in which a cutter is rotated around one center point, such as around an extruded pipe. See **extruder pipe and tubing.**

cut, kerf, and registration The kerf is the plastic lost and recyclable when a knife or other cutting device makes a cut. The wider the cutting device, the larger the kerf. Typically the feed length is the sum of the finished product and the kerf. In many cut-to-length applications, the length of the feed is not specifically defined at the start of the move. For example, this happens when cutting or performing other operations on preprinted webs. It is important that the cut be in the proper position with respect to the printing rather than to the last cut. In motion control, this on-the-fly adjustment to the final positioning is called *registration.* Performing registration moves can be called *registration moves* or *indexing on-the-fly.* See **kerf; thermoforming, preprinting.**

cut-off See **blow molding, extruder mold pinch-off.**

cutter A device that is used to produce clean and accurate cuts. The best cuts come from quickly slicing material rather than chopping, which can distort the plastic and result in uneven cuts. The criteria in selecting a knife for a particular cut are attack angle, force required, and cut time. Attack angle describes the angle between a blade's cutting edge and its axis. A high attack angle means a good slicing action, whereas a zero attack angle means a chopping action. Force required depends on the size, density, hardness, and composition of the material. See **abrasive; auxiliary equipment; dicer; die-face pelletizer; fiberglass chopper; flash scarfing; kerf; machining; material, cutting burr-free; reinforced-plastic cutting; saw.**

cutter, die A device or machine that cuts shapes from sheet material or stock by striking it sharply with a shaped knife known as a steel-rule die. Also called *blanking, clicking,* or *dinking.* See **machining and punching.**

cutter die, kiss-cut A die that cuts through a face sheet to a liner but not through the liner.

cutter, guillotine A cutter that uses a wide-blade operating in an up-down motion. It is used in different fabricating lines such as for extruder take-off cutting operations, and stacks of sheets. See **machining.**

cutter, rotary A machine that has rotary knives that act in conjunction with stationary blades.

cutting, water-jet Water emitted from a nozzle under high pressure of 70 to 420 MPa (10 to 60 ksi) or higher at mach 2 speed. It can cut through most plastics, including RPs, without creating heat or dust and without exerting lateral force on the material being cut. This action eliminates deformation of the cut edge. If abrasives, such as garnet powder, are added to the jet water stream, it will cut through virtually any material that includes aramid fibers and titanium.

cut-to-length control See **extruder-web tension control, slippage and tearing.**

cyanate plastic A thermoset plastic that is derived from bisphenols or polyphenols and is available as monomers, oligomers, blends, and solutions. Also known as *cyanate esters, cyanic esters,* or *triazine plastics.*

cyanoacrylate See **adhesive, cyanoacrylate.**

cybernetics The study of control and communication in people and machine. Technically the term means the "human use of human beings" that would "render unto people the things that are people's and undo the automatic control the things which are the controller's." The ultimate in control is the computer; however, the human brain will always be unbeatable in innovation. See **controller; computer; design; problems and solutions; productivity.**

cyborg A person who is augmented with technological attachments. The first International Symposium on Wearable Computers was cosponsored October 1997 by MIT and Georgia Tech. in Cambridge, MA.

cycle The complete repeating sequence of operations in a process or part of a process. One cycle represents the time period, or elapsed time, between a certain point in one cycle and the same point in the next. It is the time for fabricating a part that repeats itself. See **fatigue cyclic load; injection-molding cycle time, shortened; load cycle; load cycle ratio; mold gate size; servo control.**

cycle, dry A cycle where no material is used. It usually is conducted for test purposes.

cylinder See **barrel.**

cycling material See **material cycle.**

cycloalkene copolymer plastic (COC) A family of plastics derived from using metallocene catalysts. These thermoplastics are transparent as glass but far less fragile. Depending on their type and molecular structure, they have a high degree of thermal stability, resistant to chemical reagents and ultraviolet radiation, and a low level of moisture absorption.

cyclohexane A colorless liquid with a pungent odor. It is used in the production of nylon and as a solvent for cellulose ethers.

cyclohexanone An oily, water-white to pale yellow liquid with a slight odor of peppermint and acetone. It is used in the preparation of PVC and its copolymers, methyl methacrylate ester plastics, adipic acid, caprolactam, and metal degreasing. Also called *ketohexamethylene* or *pimelic ketone.*

cyclone See **dust collection, cyclone.**

cyclyd See **coating, air-drying alkyd plastic.**

Cycolac General Electric Plastic's trade name for its family of ABSs and their alloys.

cylinder See **barrel.**

D

Dacron DuPont's trade name for its family of thermoplastic polyester fiber made from PET. Available as filament, yarn, tow, and fiber fill. See **medical applications.**

dam See **reinforced plastic molding dam.**

damage tolerance **1.** A design measure of crack-growth rate. Cracks in damage-tolerant designed structures are not permitted to grow to a critical size during expected service life. See **crack-growth rate. 2.** A measure of the ability of products to retain load-carrying capability after exposure to sudden loads such as an impact drop. See **tolerance, damage.**

damping The loss of energy, as dissipated heat, that results when a material or material system is subjected to an oscillatory load or displacement. Perfectly elastic materials have no mechanical damping. Damping reduces vibrations (mechanical and acoustical) and prevents resonance vibrations from building up to dangerous amplitudes. However, high damping is generally an indication of reduced dimensional stability, which can be very undesirable in structures carrying loads for long time periods. Many other mechanical properties are intimately related to damping; these include fatigue life, toughness and impact, and wear and coefficient of friction. See **design energy and motion control; design spring; elastomer; hysteresis, elastic; nonresonant forced and vibration technique; resonant forced vibration; torsional pendulum; vibration, free.**

damping capacity A measure of the ability of a material to absorb vibration by converting mechanical energy into heat. It is equal to the area of the elastic hysteresis loop divided by the deformation energy of a vibrating material. It can be calculated by measuring the rate of decay of vibrations induced in a material. See **ethylene acrylic elastomer; modulus, dissipation factor; vibration.**

damping coefficient The characteristic function of a system, the parameter of which characterizes the nature of damping of the transient response.

damping, critical In dynamic mechanical measurement, that damping required for borderline condition between oscillatory and nonoscillatory behavior. See **dynamic mechanical measurement.**

damping curve See **dynamic mechanical analysis, alpha loss peak.**

damping, dash pot A device for damping down vibration using a fluid or air hydraulic system where its piston is attached to the part to be damped. It absorbs shocks by reducing the rate of change in the momentum of moving parts of machinery. See **auxiliary equipment; fabricating process type.**

damping factor See **electrical loss angle, tangent.**

damping gamma loss peak In dynamic mechanical measurement, the third peak in the damping curve below the melt, in order of decreasing temperature or increasing frequency.

damping index In dynamic mechanical behavior, a measure of damping being defined as the number of oscillations between two arbitrary fixed boundary conditions such as the amplitude in a series of waves. It is principally used in torsional analysis. See **dynamic mechanical measurement; test, torsional.**

damping, internal See **elasticity, an-.**

damping, mechanical A damping that gives the amount of energy dissipated as heat during the deformation of a material that is subjected to an oscillatory load or displacement. Perfectly elastic materials have no mechanical damping. Damping terms may be calculated by many methods that include use of the logarithmic decrement and the area of the hysteresis loop. See **dynamic mechanical measurement; elastomeric shape factor; energy; hysteresis loop; resonant forced vibration.**

damping, oscillatory load See **dynamic mechanical measurement; resonant forced vibration.**

damping, specific capacity A measure of the damping of a material when its dynamical behavior is considered. It is defined as the ratio of the energy dissipated per cycle of the alternating stress field to the maximum energy stored or the elastic energy. See **dynamic mechanical measurement.**

damping vibration See **dash pot; torsional pendulum.**

dancer roll See **extruder roll, dancer.**

Danner process A mechanical process for continuous drawing material, such as glass cane or tubing, from a rotating mandrel.

dart drop test See **test, dart-drop impact.**

DART software A diagnostic software expert system, developed by IBM, that is used to diagnose equipment failure problems. It does not hold information about why equipment fails but instead contrasts the expected behavior with the actual behavior of the equipment to diagnose the problem. See **computer software; fabricating process.**

dash pot A device used for damping down vibrations such as in hydraulic systems. It consists of a piston attached to the part to be damped and fitted into a vessel containing fluid or air. It absorbs shocks by reducing the rate of change in the momentum of moving parts. See **damping; vibration.**

data See **business bookkeeping; computer A-scan; computer databank; computer database; computerized electronic document and retrieval system;**

computer optical data storage; fabricating, asynchronous; performance, predicting; plastic data, theoretical versus actual value; plastic properties; production data acquisition; sampling plan; statistical data collection; test data and uniform standards.

data, B-scan A means of data presentation that provides a cross-sectional view of the test piece.

data, confidence level See **A-basis; B-basis; S-basis; typical basis.**

data-management system (DBMS) A computer system with management and administrative capabilities for control of record storage, selection, updating, formatting, and reporting from a database. See **business; computer database; plant control; technical writing.**

datum A basis for calculating or measuring. The datum has the dual nature of being both a theoretically perfect element of part geometry and when a part is actually produced. See **perfection.**

da Vinci's dream See **aircraft, Gossamer Albatross.**

daylight opening See **clamping, daylight-opening.**

day-to-night light switching See **plastic, light-switchable.**

dead control band See **control band, dead.**

dead load See **load, dead.**

dead time See **time, dead.**

deaerate To remove air from a plastic to obtain its maximum performance. Techniques used during processing include venting and applying vacuum. See **air entrapment; debulking.**

debond **1.** An area within the bonded interface between two adherends in which an adhesive failure or separation has occurred. See **adhesive.** **2.** A deliberate separation of a bonded joint usually for reworking or repair purposes. See **joining.** **3.** An unbonded or nonadhered region, such as in reinforced plastics, where a separation at the fiber-matrix interface is due to strain incompatibility. See **test, laminated curved-bar delamination analysis.** **4.** Accidental damage.

debossed See **mold cavity, debossed.**

debug To find or correct mistakes in a problem area such as the processing line or a process control program. See **hypothesis; problems and solutions.**

debulking **1.** The process in which air is squeezed out of reinforced plastic prepregs in order to promote fiber-matrix adhesion that in turn improves part performances. See **reinforced plastic.** **2.** The compacting of a thick laminate under moderate heat and pressure and/or vacuum to remove most of the air, to ensure seating on a tool, and to prevent wrinkles. See **deaerate; laminate.**

debur See **deflashing; flash; trim; tumbling.**

decal A printed or decorated design on a temporary carrier, such as plastic film, paper, or aluminum, that is used for identifying or decorating a part. The imprint is adhered to the plastic (or other materials) surface by means of a pressure-sensitive adhesive. Also called *decalcomania* or *decal transfer*. See **adhesive, pressure-sensitive; decorating; inlay or overlay; label; printing; printing, screen; dye transfer, sublimable.**

decay, radiation See **curie.**

decibel (dB) A unit expressing the relative intensity of sounds on a scale from zero for the average perceptible sound to about 130 dB for the average pain level. A decibel is 10 times the common logarithm of the ratio of two like quantities proportional to power and energy (electric and acoustic). Thus one dB corresponds to a power ratio of $10^{0.1}$ and ndB corresponds to a power ratio of $(10^{0.1})^n$.

decimal number system A system that was conceived in the sixteenth century when there was a great confusion of units of weights and measures. It was not until 1790 that the French National Assembly requested the French Academy of Science to create a system suitable for adoption by the entire world. This system based on the metre (meter in the United States) as a unit of length and the gram as a unit of mass. See **digit; meter; number marker; SI; weight; Appendix B, Conversion Tables.**

deck See **platen.**

deckle rod **1.** See **die deckle system.** **2.** In manufacture of paper, the width of the web sheet as it comes off the wire carrier. See **fourdrinier.**

decolorizing agent A material that removes color by a physical or chemical reaction. See **bleaching agent; carbon black, animal; colorant.**

decomposition The process by which bacteria, enzymes, and fungi break down and stabilize organic waste products. It is fundamentally a chemical change. In simple decomposition, one substance breaks down into two substances, such as water yields hydrogen and oxygen. In double decomposition, two components break down and recombine to form two different compounds, such as $2HCl + CaCO_3 = CaCl_2 + H_2CO_3$. In some cases heat is absorbed or otherwise it is released. Decomposition may occur as a result of (1) reaction at room temperature, (2) heating in air, (3) electrolysis of inorganic materials, (4) bacteria or enzyme action (fermentation), (5) radiation (photodegradable), and (6) heating in the absence of air (pyrolysis or thermaldegradation). See **biodegradable versus photodegradable; degradation; distillation, destructive; electrolysis; molecular decomposition; photodegradable; pyrolysis; waste; zymoplastic; zymurgy.**

decomposition, digestion The decomposition of processed organic wastes into methane and carbon dioxide under oxygen-starved conditions. See **carbon dioxide.**

decomposition temperature The degree of heat at which decomposition begins. For product applications having moderate thermal requirements, thermal decomposition may not be a problem. Some plastics can resist or provide some degree of resistance; their temperatures range from 500 to 1,000°F (260 to 540°C). Decomposition is largely determined by the elements and bonding within the molecular structures, as well as the characteristics of additives, fillers, or reinforcements that may be in the compounds. See **plastic.**

decompression See **melt-pressure decompression.**

decompression screw See **screw decompression zone; screw venting; venting.**

decontamination See **radioactive decontamination.**

decorating The finishing of certain plastic products by adding decoration that includes printing or functional service effects. Plastics are unique in that decoration and color can be added prior, during, or after fabrication. The different decorating methods provide different capabilities and benefits, such as better quality and second surface graphics, decoration on subtle curves and embossing, design versatility, dry processes that eliminate volatile organic compound issues, durability and tamper proofing, economical advantages for multiple colors, graphic flaws eliminated prior to molding, no-label look, recessed label area eliminating collection of dirt, scrap reduction or elimination, and secondary step to printer elimination. Many different basic methods are used to decorate all types of products; certain methods are used for specific type products. See **aluminum foil; bottle lug; casting; chrome plating; coating; coextrusion; coinjection molding; colorant; decal; decorative sheet; embossing; encapsulation; fabric, knitted; film decorating; film perforating; finish; flocking; foil decorating; injection molding, in-mold; injection molding, two-shot; in-mold decorating; in-mold operation; label; lettering, recessed; metallizing, vacuum; molded lettering and surface decoration; potting; printing; printing, Acrobot; printing, roll-leaf; printing, screen; screw marbleizing; sheet overlay; spray-paint coating; stamping; stamping, hot; texturizing; therimage; volatile organic compound.**

decorating dye transfer, sublimable See **dye transfer, sublimable.**

decorating, extruder roll See **extruder roll, decorating.**

decorating, fill-and-wipe For parts having depressed letters or designs, the wiping off of excess paint after application, leaving the paint remaining only in the depressed areas. Also called *spray and wipe* or *wipe-in*. See **paint.**

decorating preparation problem With surface decoration, cleaning and preparing the surface in the correct manner for the decorating method used. Some of the common causes of failure are contamination from processing lubricant, dust, natural skin greasiness, excess plasticizer on the surface, moisture, and frozen strain in plastic. Each plastic (material type with their different additives, fillers, etc.) is to be considered separately when selecting coatings, thinners, decals, and foils. Some surfaces, particularly thermoplastics, are prone to solvent attack. Frequently, it is necessary to preheat, flame-heat, or chemical treat a plastic surface before applying the decoration. Static electricity on surfaces tends to cause major problems; airborne impurities become attracted and settle on the surfaces. There is equipment used to eliminate static charge. Decorating any material should be carried out in clean, controlled-room conditions. See **cleaning; electrical corona discharge treatment; surface treatment.**

decorating pretreatment Factors such as molecular weight, method of manufacture, processing conditions, processing flash, and the form and shape of the part that all affect decorating and paint adhesion. This can involve nothing more than water cleaning the part of dirt or other residue. For some plastics, such as the polyolefins with their waxlike surfaces, more involved treatments are required. However, many plastics require their special type of surface treatment prior to decorating. Methods used include solvent treatment (hot or cold), etching using strong oxidizing agents, flame or heat treatment, mild sandblasting, corona or arc discharge, mechanical abrasion, primer coat, gas plasma, and machining. See **chemical etching; electrical corona discharge treatment; fabricating process type; flame treatment; mold flash; molecular weight; primer; solvent; surface finish.**

decorating primer See **primer.**

decorating, removing mold-release residue before Eliminating the release agent, which can cause poor bonding of decorations or finishing the part's surface. Zinc stearates are the least harmful, and silicones can be very damaging. Treatments are used to remove the undesirable agents. If possible, do not use an undesirable release agent, and regardless of type used apply sparingly. See **decorating pretreatment; mold release agent.**

decorating, second-surface A method of decorating a transparent plastic part from the back or reverse side. The decoration is visible through the part but is not exposed to the environment or other damaging conditions such as people.

decorating, spray-and-wipe See **decorating, fill and wipe.**

decorating, steel See **photoetching tool.**

decoration See **blow molding, extruder blow-action.**

decorative sheet A decorative sheet, usually plastic, used during processing such as laminating or molding, where it becomes an integral part of the fabricated part. See **decorating; injection molding, in-mold; laminate, decorative.**

deep drawing sheet A thermoplastic sheet material that is capable of being formed into large components such as refrigerator liners by vacuum forming. See **thermoforming.**

deep well The location of a sensor, such as a temperature sensor in a plasticating barrel, as close as mechanically possible to the plastic melt being processed.

Deere JD/GTS software A John Deere/Group Technology System (Moline, IL) analytical tool. See **computer software.**

defect A flaw. Different terms are used (throughout the industry and this book) to identify defects in plastic materials, fabricating equipment, and products. See **adhesive stringing; alligatoring; automation, vision; applesauce surface; bleed; blister; blockage; bloom; blowhole; blow molding, extruder pock mark; blush; burn line; chalking; coating, defective; compression buckling; crack, hairline; crazing; definition; degradation; die spider line; electrostatic discharge detector; extruder film arrowhead; extruder film cooling roll versus quench-tank; fin; fish-eye; flash; fracture; freeze-off; frosting; gas pocket; gel; globule; migration; molded-part cosmetics; orange peel; paint framing defect; pimple; pin hole; pit; plastic failure or success; pocket, plastic; plastic product failure; plate-out; problems and solutions; processing and patience; processing defect; quality level, acceptable; run; sag; sampling plan; scale; segregation; shark skin surface; sheeter line; sink mark; speck, black; splay mark; stain, contact; starved area; streak; stress whitening; striation; surface finish; testing; test, nondestructive; trim; troubleshooting; troubleshooting flaw; void; weld line; yellowing; zero defect.**

defendant See **legal matter: defendant.**

definite proportion law See **element, definite proportion law.**

definition A written and graphic explanation. Definitions are necessary in all industries (designers, fabricators, societies, trade organizations) and in all legal regulations (local, state, federal, worldwide). For example, to enforce a law, the FDA, the court, and others are obligated to interpret the language of the law and inevitably stretch definitions rather far. The challenge for FDA and others is to keep them within the bounds of reason. Thus, care is required to ensure that a definition is specific, complete, concise, and not subject to change. See **art and science; composite; design; Dominick; elastomer; fabricating process; people's challenge; perfection; polymer chemistry terminology; plastic; quality control; recycled plastic; tooling; toxicology; troubleshooting flaw; Appendix A, List of Abbreviations.**

deflashing Removing flash from a plastic product, usually a molding. Several different methods are employed that include low temperatures of dry ice and cryogenic. See **cleaning; finish, blast; flash; ice, dry; molding flash line; pressure-blasting; spin trimming; trim; tumbling.**

deflashing, airless blast See **finish, blast.**

deflashing blow mold See **blow molding, extruder mold deflashing.**

deflashing, cryogenic An efficient method of deflashing parts, particularly when small and numerous, using cryogenic tumblers and shot blast. Liquid nitrogen or dry ice is used at −320°F (−196°C). The parts can be frozen by liquid nitrogen and then blasted usually with a plastic media while tumbling in a basket sealed in an enclosed chamber. The air moving system can be sprayed at about 225 psi (1.6 MPa). Advantages of this procedure include accuracy, repeatable deflashing, and reduced finishing costs. See **cryogenic; ice, dry.**

deflashing, pressure-blasting A method that utilizes a stream of small pellets, usually crushed fruit pits or others that are not as hard as the plastic being deflashed, thrown at high speed at the molded parts that are tumbling over a continuous moving belt or in a perforated container or basket.

deflashing, wheelabrator Deflashing molded and other parts by bombarding with small particles at high air velocity.

deflection **1.** In processing, such as extrusion or molding, the distortion that pressure causes to the die, mold, clamping press, or associated equipment. **2.** The deformation or displacement from a part's original contour or shape. **3.** The linear distance that a test specimen bends under stress at the center from no load to stated load when loaded as a beam. See **flexural testing.**

deflection, residual See **residual deflection.**

deflection temperature under load versus crystallinity A high degree of crystallinity, as in HDPE, PP, and nylon, has little or no effect on the rigidity of the glassy amorphous state at low temperatures and only minor effect on the phenomenon of the glass transition temperature. It introduces so much stiffening into the flexible amorphous state that the material becomes quite tough and rigid. This tough rigid state can be extended out to much higher temperatures and thus greatly broaden the range of useful rigid properties, until true crystalline melting occurs quite sharply to a fluid liquid state. See **crystalline plastic; glass transition temperature.**

deflocculation The dispersion of colloidal particles within a liquid dispersion. See **colloidal.**

defoamer additive A foam reducer that facilitates the removal of air entrained in a mix during high-speed blending in liquid plastic systems. For example, in potting and encapsulation applications entrained air could cause surface bubbling and might even occasionally arc with electrical devices. The additive is optimized during vacuum and drying processes. Additives also serve as filler lubricants, wetting agents, and surface-tension depressants, all of which contribute to air release and aid to minimize initial air entrapment. Silicones and related blends of silicones are popular defoamers. See **air entrapment; antifoaming agent.**

deformation A part of the total deformation of a body that occurs immediately when the load is applied but that remains permanently when the load is removed. See **elongation; energy deformation; melt elasticity; melt flow; mold deformation; resilience, impact; rheology.**

deformation, affine A type of deformation in which each element in the volume of a product distorts in the same way as does the volume as a whole.

deformation analysis See **test, nondestructive moire fringe analysis.**
deformation and toughness Deformation or elasticity is an important attribute in most plastics providing toughness. However, some plastics with no deformation are extremely tough. This is particularly true for reinforced plastics. For designs requiring such traits as toughness or elasticity, this characteristic has its advantages, but for other designs it is a disadvantage. However, there are materials that are normally tough but may become embrittled due to processing conditions, chemical attack, prolonged exposure to constant stress, and so on. A high modulus and high strength, with ductility, is a desired combination of attributes. However, the inherent nature of most plastics is such that their having a high modulus tends to associate them with low ductility, and the steps taken to improve one will cause the other to deteriorate except RPs. See **coefficient of elasticity; elasticity; strain and elasticity; toughness; viscoelasticity.**
deformation, anelastic A portion of the total deformation of a body that occurs as a function of time when load is applied and that disappears completely after a period of time when the load is removed. In practice, the term also describes viscous deformation.
deformation, elastic A deformation in which a material returns to its original dimensions on release of the deforming load or stress. See **deformation, plastic; energy deformation; energy, plastic work; stress, elastic limit; viscoelasticity, linear.**
deformation, immediate set **1.** A defect that is determined by the measurement taken immediately after the removal of the load causing the deformation. **2.** See **mold deformation.**
deformation, inelastic The portion of deformation under stress that is not annulled by removal of the stress. See **stress.**
deformation, permanent set The deformation remaining after a specimen has been stressed a prescribed amount in tension, compression, or shear for a specified time period and released for a specified time period.
deformation, plastic The change in dimensions of a part under load that is not recovered when the load is removed. See **deformation, elastic; ductility; extruder-web stretching and tearing; strain hardening.**
deformation under load The dimensional change of a material under load for a specific time following the instantaneous elastic deformation caused by the initial application of the load. See **creep; designing with the pseudo-elastic method; flow, cold; load.**
deformation, viscous A portion of the total deformation of a body that occurs as a function of time when load is applied but that remains permanently when the load is removed.
deformer See **antifoaming agent.**
degassing See **mold breathing.**
degating See **mold-gate degating.**
degradability Ability to be broken down into very small particles with large surface areas and reduced molecular weight. Biodegradable and photodegradable products accomplish this differently and have different processing and environmental requirements. See **biodegradable versus photodegradable; landfill and degradation; molecular weight.**
degradable Capable of being broken down into natural elements or simpler compounds under normal environmental conditions. See **biocide; biodegradable waste; catalyst, enzyme; decomposition; engineering, genetic; photodegradable; photooxidation agent.** Active chemical compounds are used as preservatives to control degradation; those that produce death are termed *biocides*. Many chemicals may inhibit the reproduction and growth of organisms without causing death. These agents have the two common classes of control agents known as *bacteriostats* and *fungistats*. See **deodorant additive.**
degradable waste See **biodegradable waste; compost; starch degradable; landfill and degradation; waste.**
degradant The substance added to promote the breakdown of a product. For example, starch may be added to plastic film so that it degrades when discarded. See **starch degradable.**
degradation A deleterious change in characteristics such as the chemical structure, physical and mechanical properties, or appearance of plastic. A degraded appearance usually means discoloration. Degradation can occur during heat processing. Factors that determine the rate of degradation are (1) residence time, (2) stock (melt) temperature and distribution of stock temperature, (3) deformation rate and deformation rate distribution, (4) the presence of oxygen or other degradation-promoting additive, and (5) the presence of antioxidants and other stabilizers. See **burned; chalking; engineering, generic; landfill and degradation; photochemistry; photodegradable; photooxidation agent; radiation-induced reaction; ultrasonic degradation; test, fusion Kling; zymoplastic.**
degradation and weatherability See **weatherability.**
degradation, melt See **screw length-to-diameter ratio.**
degradation, photodegradable See **biodegradable versus photodegradable; decomposition; photooxidation agent.**
degradation scavenger See **contamination; packaging, oxygen scavenger food; scavenger.**
degradation, scission Degradation of plastics by radiation that splits their molecules. See **radiation.**
degradation, swelling, extraction, and random The use of chemical methods such as extraction of a lightly cross-linked network by solvent to remove non-cross-linked components. Many polymer networks swell by immersion in the proper solvent or by exposure to solvent vapors. Care should be taken that swelling occurs under equilibrium conditions. Alternatively, a cross-linked net-

work may be degraded into small soluble chemical fragments. See **chemical reaction.**

degradation with water See **drying operation.**

degreasing See **cleaning, solvent.**

degree of polymerization See **polymerization, degree of.**

degree of saturation See **saturation, degree of.**

dehumidification, mold See **mold dehumidification.**

dehumidifier A device that removes moisture from plastic materials or air. See **desiccant.**

dehumidify To reduce, by any process, the quantity of water vapor within a given space. See **drying.**

dehydrating agent See **barium oxide.**

dehydration The removal of water from a material through ordinary drying, heating, absorption, chemical reaction, condensation of water vapor, centrifugal force, or hydraulic pressure. See **drying.**

dehydrogenation See **chemical dehydrogenation.**

deink See **recycled paper.**

delaminated See **adhesive, disbonded; laminate, de-; test, nondestructive temperature differential by infrared.**

deliquescence The absorption of atmospheric water vapor by a crystalline solid until the crystal eventually dissolves into a saturated solution. See **moisture.**

delivery system See **drug controlled-delivery.**

DeLorean automobile See **automobile, DeLorean.**

Delrin DuPont's trade name for its family of acetal plastics. See **satinizing.**

demand and supply See **monitoring customers and suppliers.**

demineralization See **water pollution.**

Deming, W. Edwards See **Japanese workmanship.**

demulsification See **emulsion/demulsification.**

demurrage See **cost, demurrage.**

dendritic plastic A highly branched (dendritic) precursor of synthetic plastics that lead to three-dimensional gels and networks. These systems are broadly recognized as thermoset plastics. See **gel.**

dendrimer plastic A family of three-dimensional spherical or rod-shaped nanostructures that range to about 500 angstrom units in diameter, some 0.000002 in., or the size of proteins and enzymes. They contain hollow interiors and densely packed surfaces. These plastics are unlike others because chemicals are able to control and tailor their size, shape, molecular weight, topology, and surface chemistry to a greater degree than is possible with conventional plastics. See **plastic.**

denier See **fiber denier.**

denked paper See **paper, denked.**

densification process The consolidation of loose or bulky materials. See **density, bulk; material handling.**

densify To compact to reduce volume of material such as film scrape. See **recycled film and sheets.**

density The mass of any substance per unit volume of a material that represents the absolute density. It usually is expressed in lb/ft^3 or g/cm^3. See **chemical and physical characteristics; dilatometer; electron density; electroplating current density; foamed density reduced; gravity, absolute; light densimeter; melt density; optical density; polymer cross-linked density; tex; weight; weight, material.**

density and specific gravity The density of any material is a measure of its mass, per unit volume, usually expressed in grams per cubic centimeter (g/cm^3) or pounds per cubic inch (lb/in^3). Specific gravity is the ratio of the mass in air of a given volume compared to the mass of the same volume of water, both being measured at room temperature (23°C or 73.4°F). Since this is a dimensionless quantity, it is convenient for comparing different materials. Like density, specific gravity is used extensively in determining part cost versus average part thickness, initial sheet thickness, product weight, and quality control. It is frequently used as a means of setting plastic specifications and following product consistency.

In crystalline plastics, such as PE, density has a direct effect on properties such as stiffness and permeability to gases and liquids. Changes in density may also affect some mechanical properties. The ASTM D 792 standard provides the relationship of density to specific gravity at 23°C (other tests include ASTM D 1505 and ISO 1183): density (g/cm^3) = specific gravity × 0.9975, also specific gravity × 0.0361 = $lb/in.^3$ For greatest usefulness, density needs to be measured to an accuracy of at least ±0.001. Sample shape is not an issue, but the sample must be completely wettable in the liquid and contain no voids (per the standards using a gradient or liquid displacement method). See **melt density; specific gravity.**

density, apparent The weight in air of a unit volume of material including voids usually inherent in the material. Also called *bulk density* with materials such as molding powders.

density, bulk The ratio of weight to volume of a solid material including voids. It also refers to loose form (bulk) material such as pellets, powders, flakes, and compounded molding material. See **bulk factor; compaction; densifier; material handling.**

density, gross The density of unprocessed plastic.

density, true The mass bulk density divided by true (pore or void free) density.

dental amalgam The preferred composite filler of a silver-colored alloy of mercury filling that was developed during the early 1800s. It is less expensive than cast restoration such as gold inlay and to date more durable than composite plastic-metals (tooth colored plastics).

dental market Useful preventative and restorative dental materials such as fast-cure plastics, including epoxy and amine-peroxide initiator systems, acrylics, and TP polyesters. The largest volume of plastics is in the construction and repair of prosthetic devices such as denture bases, repair and relining materials, and plastic teeth. Other uses include protective sealants, elastomers for impressions of oral structures, mouth protectors, patterns for metal inlays, oral implants, and operative dentistry (restore, cavity liners, etc.). See **market; medical market.**

deodorant additive A material that prevents the development of bad odors. With odorants, they produce a fragrance. Or mask distasteful odors and deodorizers. Deodorants prevent microorganisms from reacting with organic matter to produce odors. Two major organisms that initiate attacks are bacteria and fungi. In the presence of heat and moisture, for example, bacteria from the skin could react through perspiration with products such as certain plastic clothing to develop odor unless an antimicrobial agent is present. The most popular is organometallics, primarily used in PE and PVC trash bags. See **antimicrobial agent; bacteria; bacteria, aerobic; odorant agent; fragrance concentrate.**

dependent variable See **variable, dependent.**

depletable Nonreplaceable.

depolymerization See **polymerization, de-.**

deposition The process of applying a material to a base substrate by vacuum, electrical, chemical, screening, or vapor methods, often with the aid of a temperature and pressure container. See **chemical vapor deposition; mold-cavity coating.**

deposition, legal See **legal matter: plaintiff.**

deposit law See **legal matter: bottle bill.**

depressant See **viscosity depressant.**

depth In the case of a beam, the dimensions parallel to the direction in which a load is applied. In a container, it is the internal depth. See **screw depth.**

depth dose See **radiation depth dose.**

derivative See **mathematical derivative.**

derivative control See **control, derivative.**

desalination See **water, desalinizing ocean.**

desiccant A hygroscopic material such as activated alumina, calcium chloride, silica gel, or zinc oxide that can be used for drying purposes because of its affinity for water. They absorb water vapor from the air. A desiccant is the heart of a dehumidifying dryer system for hoppers, molds, and so on. Most plastics can absorb 3 to 15% of their dry weight, while desiccants absorb 20 to 1,200%. The most commonly used is a synthetic crystalline metal alumina-silicate from which water of hydration has been removed, permitting it to adsorb moisture. In use it becomes saturated with moisture, requiring it to be regenerated by heating it to drive off moisture. The drying action is called *selective adsorption*. This drying cycle is repeatable many times. See **absorption; alumina, activated; dehumidifier; moisture; mold sweating; water.**

desiccant drier A type of hot-air drier in which the moisture is removed from the air by means of a desiccant such as silica gel. See **mold dehumidification.**

desiccator A tightly closed vessel or container that contains a desiccant. It is used for drying plastics, molds, dies, and so on. See **mold storage.**

design The process of devising a product that fulfills as completely as possible the total requirements of the user and at the same time satisfies the needs of the fabricator in terms of cost-effectiveness (return on investment). The efficient use of the best available material and production process should be the goal of every design effort. Design guidelines for plastics have existed for over a century, producing many thousands of parts meeting service requirements, including those requiring long life. See **art and science; aspect ratio; computer-aided design; computer-assisted design and drafting; computerized knowledge-based engineering; computer software; design optimized; empirical; experience and science; intelligence, artificial; legal matter; design material optimization; mathematical dimension; plastic, long-life; productivity; quality optimization goal; risk, acceptable; servo-control-drive reliability; statistical equivalent loading system; theory.**

design accuracy Exactness; freedom from errors; conformity to a standard. When applied to a method, it denotes the extent to which bias is absent; when applied to a measured value, it denotes the extent to which both bias and random error are absent. A fabricating system can be very precise and have poor accuracy. A manufacturing target of consistent, repeatable fabrication requires more than tight mechanical equipment standards, tight plastic material standards, and precise instruments with fast-integrated control response, but these conditions can go a long way to meeting the target. Instruments need to be calibrated to fixed standards. To achieve accuracy, the pressure, temperature, speed, and other control parameters must be calibrated to traceable standards. By measuring against known standards, the design accuracy of the measurements can be determined. There can be parameters that cannot be quantified, so these will contribute to the variability and limit the accuracy that can be obtained. Variations in molecular weight, pellet size, virgin/recycled mixes, and so on can effect the process. Unfortunately, these variations are not often recognized or easily identified. Also called *deviation*. See **accuracy; accuracy and repeatability; decimal number system; deviation; deviation, standard measurement; machine, coordinate measuring; measurement; molded-material surface measurement; performance, predicting; quality; reliability; sensor, dynamic accuracy of a.**

design advantage, plastic See **plastic advantages and disadvantages; structure.**

design allowable A statistically defined material property with allowable strengths, usually referring to stress or strain. See **design safety factor; A-basis; B-basis; S-basis; typical basis.**

design analysis Using plastics (as with metals, aluminum, wood, etc.) with maximum advantage and minimum risk of failure by becoming familiar with their behavior. See **computer-aided; definition, art of; design technology; economic efficiency and profitability; design-failure theory; people's challenge; performance, predicting; risk, acceptable.**

design and cost, technical cost modeling See **technical cost modeling.**

design and product liability In designing products, equipment, and testing procedures, liability factors need to be considered. These factors include top management support; liability issues as recognized by design, production, and other people's involvement; all possible safety devices; communication with and documentation for the customers or buyers regarding any potential problems and hazards; outside-source parts' safety programs and documentation; collecting the history of the same or similar part; and feedback on performance and problems with recall system. See **legal matter: product liability law.**

design and risk See **risk, acceptable.**

design and stress cracking See **environmental stress cracking; orientation, accidental; stress crack; stress whitening.**

design and tolerance The complex interactions of the many processing factors, including plastic properties and behaviors, geometry of the part, toolmaking quality applied to manufacture of dies or molds, and the processing conditions and fluctuations inherent in the equipment and materials. See **plastic material and equipment variable; tolerance.**

design and weathering The effect of weather on materials with short or prolonged outdoor exposure. The process of disintegration and decomposition that can occur as a consequence of exposure to the atmosphere with its oxygen, contaminants (smoke, chemicals, etc.) and the action of frost, water, and heat. See **aging; antioxidant agent; antiozonant agent; weatherability; weathering, artificial.**

design approach See **engineering approach versus practical approach; kiss.**

design, aspect ratio See **aspect ratio; reinforcement, disk; reinforcement, whisker; slenderness ratio.**

design assembly The putting together of parts. It is an irrefutable fact of nature that the fewer the parts, the less that can go wrong. See **assembly; joining, design; design disassembly.**

design, automobile See **automobile, composite.**

design, basics of flow die The non-Newtonian behavior of plastics melt makes its flow through a die somewhat complicated. A simplified equation was obtained from a high-speed computer study during the early 1960s by G. P. Lahti. He did this work at DuPont and later went to NASA. This excellent foundation uses an empirical approach that pertains to extrusion die channels of several shapes. Flow equations for dies of simple shapes, such as circular or rectangular channels, were known in the previous century; M. J. Boussinesq (France) first developed them in 1868. Formulas for pressure drop through more complex channels had not yet been developed because the researchers required extremely complicated mathematics. The following equations were used: $Q = (1/\mu)\ (\Delta P/L)\ (BH^3/12)\ (F)$ or $\Delta P = (12\mu QL/BH^3)\ (1/F)$; where H = minimum dimension of cross-section, in (mm); B = maximum dimension of cross-section, $B = \geq H$, in (mm); ΔP = pressure drop; Q = volumetric flow rate; L = length of channel; and F = flow coefficient.

To account for the entrance effect when a melt is forced from a large reservoir, the channel length (L) must be corrected or the apparent viscosity must be used once it has been obtained from shear rate/shear stress curves for the L/H value of the existing channel. The entrance effect becomes negligible for $L/H > 16$. This single equation can be used for a variety of flow channels.

Based on knowing the product geometry, plastic viscosity, and pressure drop, the volumetric flow rate (Q) can be calculated. Calculations are also presented for (1) flow in two or three directions that exists in a tapered die, (2) detailed discussion including limitations and assumptions for regular and irregular shapes are made for slow viscous melts, (3) and so forth. To date various organizations have expanded the capability of CAD software programs for die designs.

design, bearing See **bearing.**

design, biomedical product The biomaterial that is used to repair, restore, or replace damaged or diseased tissues. Biomaterials also interface with the physiological environment. Synthetic biomaterials, such as plastics, metals, and ceramics, are often called biomaterials to differentiate them from natural materials. Advances in plastic science and surgery make it possible to rebuild many parts of the human body. They are widely used for intracorporeal, paracorporeal, and extracorporeal applications. Applications include (1) implants as temporary devices (surgical dressings, sutures, etc.), simple semipermanent devices (tendons, reinforcing meshes, etc.), and complex devices simulating physiological processes (artificial kidney-blood dialysis, etc.), and (2) interfacing and outside materials that include catheters, blood bags, syringes, surgical instruments, and disposables for health care delivery. See **biodegradable; biological activity; legal matter: biomaterial liability bill; medical-device packaging clarity; packaging biological substances; packaging, electronic; static charge; toxicology.**

design, biotechnology The technology that is concerned with the application of biological and engineering solutions to materials, machines, and humans. For example, biotechnology based on manipulation of genes at the molecular level is potentially useful in polymer-based materials. The target is to provide more productive manufacturing processes. Currently, the materials' value chain is overwhelmingly based on petroleum feedstocks and uses classic polymer chemistry with engineering analyses. This approach is capital intensive and creates byproducts that must be disposed of in an environmentally acceptable way. Potentials via biotechnology exist to replace parts of this system with lower-cost, less capital-intensive processes based on transgenic plants and microorganisms. For example, DuPont made a new type polyester called 3GT. When 3GT is compared to DuPont's Rynite 2GT (PET) and Crastin 4GT

(PBT), it may have a more economical processing route. Other developments include using natural organisms to convert glucose to glycerol. See **plastic and feedstock; plastic and future; plastic products, raw material to.**

design blow molding parison controller See **blow molding, extruder parison programmed-control.**

design boss A hollow or solid projection that is used for (1) attachment (insert, screw, etc.) and support of related components and (2) dimensional stability for a part, while reducing material usage. Unsupported edges of a part may be stiffened or strengthened by turning the edge or changing the plane of the wall. The result is to reduce or eliminate part warpage especially when thin wall thickness is used. Also called *stud.*

design, bottle See **blow molding.**

design, bottle-base The radius at the base of a bottle that connects the body (wall) of the container with the bottom-bearing surface of the bottle. It varies in size, depending on the geometry of the bottle. See **bottle.**

design camber A deviation from a straight edge; usually the maximum deviation of an edge from a straight line of given length.

design, cardioid A heart-shaped curve that is traced by a point on the circumference of a circle rolling completely around an equal fixed circle.

design chemical processing pump Sealless pumps that are used primarily in the chemical and petrochemical industries with no packings or seals.

design chemical structure See **designing with plastic-chemical models.**

design circular board The simultaneous, multidirectional deformation of a substance, such as reinforced plastic, in which one face of a flat specimen becomes concave and the other becomes convex.

design clearance A controlled distance by which one part of a unit is kept separated from another part by a specified distance. See **tolerance; design, snap-fit.**

design, clearance-fit A limit of size so prescribed that a clearance always results when mating parts are assembled.

design, collapsible-bottle A bellows-style collapsible container, such as bottles and tanks, that is foldable. The series of bellows overlap and fold to retain their folded condition without external assistance, thus providing a self-latching feature. This latching is the result of bringing together under self-pressure of two adjacent conical sections of unequal proportions and different angulations to the bottle axis. The swing action of one conical section moves around a fixed pivot point from an outer to an inner resting position. The two symmetrically opposed pivot points and rotating segments keep a near constant diameter as they travel along the bottle axis. These blow-molded bottles provide advantages and conveniences such as reduced storage space, transportation, and disposal space as the content is dispersed, reducing oxidation that affects certain freshness products (mayonnaise, etc.). See **blow molding; bottle.**

design, competitive See **plastic competition.**

design, computer and cybernetic See **cybernetics.**

design conceptual See **computerized knowledge-based engineering.**

design confidentiality See **design protection.**

design consolidation and minimizing material Plastic materials and processes that permit a wide variation to combine two or more parts or components into one unit. See **assembly; plastic myth and fact.**

design constraints The advantages and disadvantages of plastics and processing methods. Until the designer becomes familiar with processing, a fabricator must be taken into the designer's confidence early in the development stage and consulted frequently during those early days. The fabricator and the mold or die designer should advise the product designer on plastic materials behavior and how to simplify the design to permit easier processability. Although there is no limit theoretically to the shapes that can be created, practical considerations must be met, such as available processing equipment and cost. These relate not only to the part design but also the mold or die design, since they must be considered as one entity in the total creation of a usable, economically feasible part. See **design features that influence performance; plastic advantages and disadvantages; plastic material and equipment variable.**

design container lid See **container lid skirt shape.**

design control and quality-system regulation Detailed procedures that ensure the continual success of products meeting performance requirements. See **quality-system regulation.**

design, corrugated A material containing parallel ridges and furrows for rigidity. Different plastics and reinforced plastics are used to meet different performance requirements. The product can be a simple flat corrugated sheet or complex shapes. An example is a corrugated blow-molded symmetrical or unsymmetrical shape. Extensive use is made of small to very large-diameter extruded corrugated pipe or tubing. See **extruder pipe and tubing; extruder-blown tube; tube, collapsible squeeze.**

design, cost-modeling Computer-generated routine tasks of embodiment and detailed operation rather than the human creative activities of conceptual operation. Knowledge of the computer's capability in specific areas of interest such as machine settings, product design, and die design is necessary. Using the computer tools properly results in a much higher level of processing. See **cost; creativity; blow-molding innovation; design and cost, technical cost modeling; plastic myth and fact; productivity.**

Successfully designed products require the combination of various factors that includes sound judgment and knowledge of processing. Until the designer becomes familiar with processing, a fabricator must be taken into the designer's confidence early in development and consulted frequently. It is particularly important during the early design phase when working with conditions such as shapes and sizes. Certain features have to be kept in mind to avoid degradation of plastic properties. Such features may be called property *detractors* or *constraints*. Most of them are responsible for the unwanted internal stresses that can reduce the available stress for load bearing purposes. See **plastic and future.**

design creep See **designing with creep data.**

design deformation See **deformation and toughness.**

design, die Design of a die includes (1) minimizing head and tooling interior volumes to limit stagnation areas and residence time; (2) streamlining the flow through the die, with low approach angles in tapered transition sections; and (3) polishing and plating interior surfaces for minimum drag and optimum surface finish on the extrudate. Basically the die provides the means to spread the plastic being processed/plasticated under pressure to the desired width and thickness in a controllable, uniform manner. In turn, this extrudate is delivered from the die (targeted with uniform velocity and uniform density lengthwise and crosswise) to takeoff equipment to produce a shaped product (film, sheet, pipe, profile, coating, filament, etc.).

Pumping pressure on the melt entering the different designed die heads must meet their melt-flow patterns within the die cavities. The pressure usually ranges as follows: (1) blown and lay-flat films at 2000 to 6000 psi (13.8 to 41.3 MPa); (2) cast film, sheet, and pipe at 500 to 4,000 psi (3.5 to 27.6 MPa); (3) wire coating at 1500 to 8000 psi (10.3 to 55.1 MPa); and (4) monofilament at 1000 to 3,000 psi (6.9 to 20.7 MPa). See **computer-aided; die, coathanger; die efficiency; extruder pipe and tubing die design; melt-flow defect; zinc.**

design directional property See **directional property.**

design disassembly The two basic methods of disassembly—reverse assembly or brute force. Joining processes that are not reversible and require the use of brute-force disassembly include most inserts and welding procedures. See **adhesive; design assembly; fastener; joining-and-bonding method; insert; welding.**

design, EI theory The principle that deformation in beam or sheet sections depends on the mathematical product of the modulus of elasticity (E) and the moment of inertia (I), commonly expressed as EI. This theory has been applied to many different constructions including sandwich panels. See **design, sandwich-structure; modulus and stiffness; modulus of elasticity; moment of inertia; sandwich construction; stress-strain.**

design, electronic shielding See **electromagnetic interference.**

design energy and motion control Thermoplastic elastomers are frequently subjected to dynamic loads where energy and motion control systems are required. Products include sporting goods, home appliances, automobiles, buildings, bridges, aircraft, and spacecraft. The elastomers are used to control noise, shock, and vibration and are used in many applications strictly to accommodate motion. They are used in situations of shear, compression, buckling, and bulk. The particular application will dictate which would be best. See **damping; design, motion-control, mechanical and electronic effects; energy absorption; motion control system; thermoplastic elastomer.**

design engineering The application of graphic principles and practices to the solution of engineering problems. It is the systematic process by which a solution to a problem is created. Engineering design is a decision-making activity that uses scientific and technological information to produce a product or system. It is different in some degree from what the designer knows to have been done before and is meant to meet new needs. See **artwork; computer-aided design; computer drawing; computerized knowledge-based engineering; computer picture-level benchmark; design, graphic; design theory and strength of material; directional property; engineer; moment of inertia; performance prediction; safety, engineering; stress-strain curve; test analysis, micromechanical; toughness and area under the curve.**

design ethic See ***The Unwritten Laws of Engineering.***

design, experiment The large number of material, geometry, and process variables involved with their interactions, such as in injection molding. One approach is design of experiments (DOEs), which requires some rigorous analysis of the factors involved. See **plastic myth and fact.**

design factor of safety See **design safety factor.**

design failure theory The criteria for failure based on normal or shear stress. In many cases, a product fails when the material begins to yield "plastically." In a few cases, one may tolerate a small dimensional change and permit a static load that exceeds the yield strength. Actual fracture at the ultimate strength of the material would then constitute failure. Fatigue failure is the most common mode of failure. Other modes of failure include excessive elastic deflection or buckling. The actual failure mechanism may be quite complicated; each failure theory is only an attempt to explain the failure mechanism for a given class of materials. In each case a safety factor is employed. However, with proper part design, these failures are eliminated or can be permitted since part performance is met. See **DART software; design safety factor; dynamic fatigue; failure fault tree analysis; fatigue; hypothesis; hysteresis measurement; people's heuristic; performance prediction; plastic failure or success; plastic material and equipment variable; plastic product failure; problems and solutions; quality system regulation.**

design-failure theory, Griffith The strength of a material expressed in terms of crack length and fracture surface energy. Brittle fracture is based on the idea that the presence of cracks determines the brittle strength and crack propagation occurs. It results in a fracture rate of decreased elastically stored energy that at least equals the rate of formation of the fracture surface energy due to the creation of new surfaces. See **crack growth; fracture; fracture, brittle.**

design features that influence performance One of the earliest steps in product design is to establish the configuration of the part that will form the basis on which strength calculations will be made and to select a suitable material to meet the performance requirements. During this phase certain design features have to be kept in mind to avoid problems such as reduction of properties. Such features are called *detractors* or *constraints*. Most of them are responsible for the unwanted internal stresses that can reduce the available stress level for load-bearing purposes. Other features may be classified as precautionary measures that may influence the favorable performance of a part if they are properly incorporated. For example, something as simple as a stiffening rib is different for an injection-molded or structural-foamed part even when both parts use the same material. Familiarization of design constraints is a critical first step in design to eliminate product problems. For example, a designer might have an expensive tool (mold or die) prepared based on a plastic's shrinkage value but discovers belatedly that the plastic did not meet some overlooked design constraint and the required plastic has a much lower shrinkage value. The tool has too large a mold cavity or die opening, requiring expensive modification or replacement of the tool. See **design constraints; risk, acceptable design, finite-element analysis, computer finite-element mesh operation; finite-element analysis.**

design flow diagram See **Figure 3, Product Design Diagram Incorporating Process Selection.**

design, geodesic The shortest distance between two points on a surface. It is used in designing load-bearing structures that include plastics and reinforced plastics. See **automobile, composite; design, shape; directional property.**

design, geodesic isotensoid A design with a constant stress level in any given surface at all points in its path. Filament-wound plastic structures are extensively used. See **filament winding geodesic-isotensoid contour.**

design, geodesic-ovaloid See **filament winding geodesic-ovaloid.**

design, good manufacturing practice See **quality system regulation.**

design, graphic The principles of engineering drawings, computer graphics, descriptive geometry, and problem solving. The overall study of graphics involves the three aspects of terminology, skills, and theory. See **artwork; design, engineering; directional property.**

design guide A general guide of the design process anatomy can use the overlapping approach of chronological order, clarifying the task, conceptual design, embodiment of design, and detailed design. See **people's heuristic.**

design hinge, integral An integral fold or pivot line. Various techniques are used to fabricate thermoplastic hinges: molded-in (during injection or blow molding, etc.), cold worked, extruded, and coining. These so-called living hinges take advantage of molecular orientation to provide the bending action in the plastic hinge. An integral hinge can be molded by conventional processing techniques providing certain factors are observed. The required molecular orientation runs transverse to the hinge axis. This can best be achieved by a proper fast melt flow through a thin hinge section, using a proper high melt temperature. The main concern in integral-hinge molding is to avoid conditions that can lead to delamination in the hinge section. These include filling the mold too slowly, having too low a melt temperature, having a nonuniform flow front through the hinge section, suffering material contamination as from pigment agglomerates, and running excessively high mold temperatures near the hinge area. Postmold flexing while it is still hot also produces an integral hinge. Coining is used where the plastic at the hinge section is compressed to the desired thickness using matching bars. The plastic in the hinge section is stressed beyond its yield point after creating a necking-down effect that causes stretching or orienting of its molecules. See **closure; forming; injection molding; orientation; thermoforming, clamshell.**

design, industrial (ID) The design element of all industry that relates to research, engineering, production, and marketing activities. See **productivity.**

designing processes with models A model is used to describe a process using a mathematical equation. The mathematical formulation enables the model to be used for a variety of purposes that include design, control, and exploration of process control to study the effects of changes in process variables. See **fabricating; plastic material and equipment variable; process control.**

designing with creep data Creep data can be very useful to the designer. In sound design procedure, long-term creep information should be obtained on the prospective material, under the conditions of product usage. In addition to the creep data, a stress-strain diagram under similar conditions should be obtained. The combined information will provide the basis for calculating the predictability of the plastic performance. The factors that affect being able to design with creep data include a number of considerations, such as the following: (1) The strain readings of a creep test can be more accessible to a designer if they are presented as a creep modulus. In a viscoelastic material such as plastic, the strain continues to increase with time while the stress level remains constant. Since the creep modulus equals stress divided by strain, we thus have the appearance of a changing modulus. (2) The creep modulus, also known as the *apparent modulus* or *viscous modulus* when graphed on log-log paper, is normally a straight line and lends itself to extrapolation for longer periods of time. (3) Creep-data application is generally limited to the identical material, temperature, stress level, atmospheric conditions, and type of test. Data of a relatively short duration of 1,000-h can be extrapolated to long-term needs. Reinforced thermoplastics and particularly reinforced thermosets display a much higher resistance to creep than do the unreinforced plastic. See **creep; creep behavior, guideline; creep isometric and isochronous graph; creep loading.**

designing within variable See **plastic material and equipment variable.**

designing with models See **modeling, solid; modeling, surface; modeling, wire-frame.**

designing with plastic-chemical models Modeling of a "glassy" or vitreous state of polymers is important because the peculiar condition called glass is not very well understood or applied. This condition is often and easily realized with polymers; polymeric glasses are technologically significant. Connected with the quest for structure and properties of the glassy state is the need to understand the range of temperature, pressure (stress), and time (frequency) where the conventional states, most important liquid, undergo the glass transition or glass formation and becoming glassy. See **chemical composition and plastic properties; chemistry; glass transition; molecular-structure configuration; stress.**

designing with plastic tailor-made models Model polymers (plastics), also referred to as *tailor-made macromolecules*, were originally defined as polymer species in which the linear structure of the molecules and their average size were defined unambiguously. Also they are where fluctuations in molecular weight and in composition were very low. A broader definition now exists with the more complex molecular structures as well as their more specific properties and applications. They include branched macromolecules, block copolymers, graft copolymers, and polymeric networks with elastically effective chains of known average length. There exists accurate control of molecular structures for these polymers. Specific methods have been designed for the preparation of the model polymers, allowing proper control of the parameters governing chain growth. These methods, sometimes called *macromolecular engineering*, have been developed to synthesize structurally controlled polymers. See **computer-aided molecular graphic; copolymer; molecular structure; molecule, macro-; performance prediction; plastic; plastic properties; polymer evolution; Staudinger, Hermann.**

designing with quality See **quality control; quality level, acceptable.**

designing with smart plastic See **plastic, smart.**

designing with statistical See **statistical benefit; statistical material selection, reliability.**

designing with the pseudoelastic method Since at least the 1940s extensive research and development has applied equations for plastics based on the behavior of plastics. Many different plastic products have been designed using these equations, fabricated, and provided long service life, including those used in aircraft, buildings, boats, transportation vehicles, and deep-space antennas. For those not familiar with this type information recognize that the viscoelastic behavior of plastics shows that their deformations are dependent on such factors as the time under load and temperature. Therefore, when structural (load-bearing) plastic products are to be designed, it must be remembered that the standard equations that have been historically available for designing springs, beams, plates, cylinders, and so on have all been derived under the assumptions that (1) the strains are small, (2) the modulus is constant, (3) the strains are independent of the loading rate or history and are immediately reversible, (4) the material is isotropic, and (5) the material behaves in the same way in tension and compression.

These assumptions are not always justifiable when applied to plastics unless modification has occurred. The classical equations cannot be used indiscriminately. Each case must be considered on its own merits, with account being taken of such factors as the mode of deformation, the service temperature and environment, the fabrication method, and so on. In particular, it should be noted that the past traditional equations that have been developed for other materials, principally steel, use the relationship that stress equals the modulus times strain, where the modulus is constant. Except for thermoset reinforced plastics and certain engineering plastics, many plastics do not generally have a constant modulus. Different approaches have been used for the nonconstant situation; some are quite accurate. The drawback is that most of these methods are quite complex, involving numerical techniques that are not attractive to designers. One method that has been widely accepted is this so-called pseudoelastic design method. In this method appropriate values of such time-dependent properties as the modulus are selected and substituted into the standard equations.

It has been determined that this approach is sufficiently accurate in most cases if the value chosen for the modulus takes into account the projected service life of the product and the limiting strain of the plastic, assuming that the limiting strain for the material is known. Unfortunately, this is not a straightforward value applicable to all plastics or even to one plastic in all applications. This value is often arbitrarily chosen, although several methods have been suggested for arriving at a suitable value. One is to plot a secant modulus that is 0.85 of the initial tangent modulus and note the strain at which this intersects the stress-strain characteristic. For many plastics, particularly the crystalline thermoplastics, this method is too restrictive. So in most practical applications the limiting strain is decided in consultation between the designer and the plastic material manufacturer. Once the limiting strain is known, design methods based on its creep curves become rather straightforward. See **designing with creep data; design, reinforcement; design safety factor; directional property, isotropic; dynamic mechanical measurement; engineering plastic; load; modulus of elasticity; modulus, secant; modulus, tangent; performance**

prediction; reinforced plastic; strain; stress; structural adhesive; viscoelasticity.

designing with thermal situation Designing with thermal expansion characteristics included in the use of plastics and other materials when parts are to be fitted or restricted when subjected to temperature changes. See **coefficient of linear thermal expansion; design shrinkage; thermal.**

designing with tolerance See **melting temperature; tolerance.**

design injection-molding cycle time shortened See injection-molding cycle time, shortened.

design, innovative Blending a knowledge of materials, an understanding of manufacturing processes, and imagination of new or innovative designs. Recognizing the limits of design with traditional materials is the first step in exploring the possibilities for innovative design with plastics. Some designers operate by creating only the stylish outer appearance, allowing basic engineers to work within that outside envelope. This approach is used very successfully in certain products or in parts for furniture. Combining designing appearance with engineering creates a stylish product that incorporates the best combination of ease of processing, simple assembly, capability of repair, streamlined quality control, and other conditions. The stylish envelope that eventually emerges will be a logical and aesthetic answer to the design challenge. See **aesthetic; art and science; blow-molding innovation; computerized knowledge-based engineering; dendrimer plastic; design, biotechnology; design success; integrated circuit, plastic; plastics and the future; performance prediction; polymer, reactive; productivity; prototype; revolutionary versus evolutionary developments.**

design lubricant, reduced-friction Significantly reducing friction between two sliding surfaces is accomplished by rapidly oscillating the width of the lubricant-filled gap separating the sliding surfaces. This technique keeps the lubricant in a state of dynamic disorder, preventing the formation of molecular laying that can increase friction. Based on molecular dynamics simulations, this approach is of particular interest to designers of microscale machines. See **friction; lubricant.**

design, material optimization Designers can turn to materials as a means of dramatically improving their products' performance and cost. However, design automation has CAE/CAD/CAM tools focusing on the use of geometry as the only means of optimizing product design. About 70% of product designs are nongeometric. With over 80,000 materials (including 17,000 plastics) to choose from, the material software tools have become an asset to designers and engineers with or without experience in material characteristics. The software provides information on specific performance requirements so that only one or a few will be listed as the best material for the product. These tools let designers consider materials as a variable in design to meet specific product requirements. See **computer software; design, optimized; moment of inertia; plastic; plastic material and equipment variable; plastic material selection; plastic material type; statistical material selection, reliability of; statistical material selection, uncertainty in; test, short-time-behavior.**

design, maximum diametrical interference In interference fit design, the maximum allowable interference. An example is, for a particular hub and shaft, the per unit measurement of the shaft diameter. It depends on the types of materials used in the hub and shaft and on the ratio of the shaft diameter to the hub outside diameter. It is determined to ensure that hoop stress in the interference fit does not exceed the allowable stress of materials used. See **fit, interference.**

design, medical-device Designing medical devices, building controlled environments, and submitting devices for FDA approval are time consuming, costly activities for medical-device manufacturers. Such activities generally have a target time line with a set completion date and budget. The daily operations of manufacturing in a controlled environment present continual challenges that vary as the regulations change and the cost of manufacturing increases. A system designed to ensure efficient contamination control operations is called PACT (prevention, assessment, corrective action, and training). PACT is designed to assist supervisor, managers, and engineers with contamination control management. It involves the continuous-improvement principles of total quality management. See **design, medical-product; medical material and the environment; quality management, total.**

design, melt-flow See **melt-flow analysis; melting temperature; injection molding process control.**

design, melt-flow analysis limitation See **melt-flow analysis problem.**

design, melt-flow Cauchy-Riemann differential equation Equations that were developed to describe the melt-flow behavior of plastics. They have been applied to studying the melt flow during processing in plasticators. Patterns of different positions and locations during processing can be produced. For example, they can be related to shrinkage of plastic melt in a mold cavity during injection molding. See **design shrinkage; plasticator; shrinkage.**

design mold Particularly for injection molding, a controllable complex mechanical device that must also be an efficient heat exchanger. If not properly designed, handled, and maintained, it will not be an efficient operating device. Hot melt, under pressure, moves rapidly through the mold. Air is released from the mold cavity to eliminate melt burning or voids in the part. To solidify the hot melt, water or some other medium circulates in the mold to remove heat from thermoplastics, or heat is used with thermoset plastics. All kinds of actions can be used to operate the mold such as sliders and unscrewing mechanisms. CAD and CAE programs are available that can aid in mold design and in setting up the complete fabricating process.

These programs include melt flow to part solidification and the meeting of performance requirements. See **computer-aided; mold; mold-filling monitoring; thermoplastic; thermoset plastic; zinc.**

design-mold basics of flow The variable conditions during molding that influence part performance. Of paramount importance are gate location and controlling the cavity fill rate or pattern. The proper fill helps eliminate part warpage, shrinkage, and other problems. In the practical world of mold design, there are many instances where tradeoffs must be made to achieve a successful overall design. For example, while naturally balanced runner systems are desirable, they may lead to problems in mold cooling or increased cost due to excessive runner-to-part weights. Software flow-analysis guides allow successful designs of runners to balance for pressure, temperature, rate of flow, and so on. See **Reynolds number.**

design monocoque structure A construction in which the outer covering "skin" carries all or a major part of the stresses. The structure can integrate its body and chassis, such as in aircraft and automobiles. See **aircraft; automobile, composite.**

design, motion-control, mechanical and electronic effects Control-system selection depends on whether you need (1) a new system or a retrofit, (2) one that is 100% computer controlled or covers select functions, (3) one with leading-edge technologies or with just enough high technology to get you up and running, or (4) one that is designed in-house or by automation specialists. Different operating mechanical devices include actuators that convert the rotation of a motor into linear motion, linear guides, linear bearings, properly designed machine structure to ensure rigidity and proper mounting installation, and mechanical dampers to isolate the motion system from its environment, ensure control of inertia when components move or cause friction, avoid resonance problems, and protect against dirt. These are a few of the mechanical factors that affect the electronic design of motion control systems. The electronic engineer must understand the mechanics of motion to create a successful electronic system. To decide on electronic and software requirements, important factors such as product flow and throughput, operator requirements, and maintenance issues have to be considered. See **computer-integrated manufacture; controlled motion; design energy and motion control; drive-system control; electric motor; electric motor drive; extruder drive-energy consumption; injection-molding machine-drive system; maintenance; repeatability; robot.**

design, optimized With plastics to a greater extent than other materials, an opportunity exists to optimize product design by focusing on material composition and orientation, as well as structural member geometry. There is also an important interrelationship among shape, material selection (including unreinforced and reinforced, elastomers, foams, etc.), consolidation of parts, fabricating selection, and others that provide low cost to performance products. See **aspect ratio; design, material optimization; moment of inertia; performance prediction; plastics advantages and disadvantages; plastic material and equipment variable; plastic material selection; plastic material type; quality optimization goal.**

design packaging Creating packages that fulfill their requirements. Designers must (1) define and meet the environment requirements, (2) design and fabricate the prototype package, (3) define product fragility, (4) choose the proper protective or barrier materials, (5) design and fabricate the product that was prototyped, and (6) test the package. Recycling is also a goal. Packaging failures can be costly and incur legal problems. See **barrier plastic; legal matter: plaintiff; medical packaging; packaging; recycling; waste, source reduction of.**

design performance The effectiveness of a design. For example, a house needs to stand up to the forces of a catastrophic hurricane, so low-pitched roofs are less vulnerable than steeper roofs because the same aerodynamic factors that make an airplane fly can lift the roof off the house. Also, the roof must be properly attached to the building structure. Other examples include the advantage of basic beam structures as well as hollow-channel, I-, and T-shapes designed to provide efficient strength-to-weight products. See **performance prediction; plastic, long-life; test, short-time-behavior.**

design, pipe A major product made from plastics is pipes for use on the ground, underground, and in water. The largest use is in transporting water, gas, waste matter, and so on. Thermoplastic, such as polyvinyl chloride and polyethylene plastics, provides most of the world's pipes. The other major product is reinforced plastic, principally using glass fiber with thermoset polyester plastic, that uses bag-molding and filament-winding fabricating techniques. ASTM standards use the term *reinforced thermoset resin pipe* (RTRP). Since at least 1944 pipe design equations have been used that specifically provide useful information to meet internal or external pressure loads. See **directional property; extruder pipe and tubing die design; filament winding; pipe; pipe, water deterioration; reinforced plastic-bag molding; reinforced plastic pipe; sewer rehabilitation; underground pipe.**

design, plant layout via computer To speed up installation and startup, a computer workshop program can generate models of plant primary and secondary equipment to be installed prior to the arrival of the equipment. An example of a specialist in this operation is the Up and Running Co. (New Haven, CT), which calls its program PREVIEW. The program takes two-dimensional drawings and converts them into three-dimensional models. Services are installed such as electric power, air, water, and material handling lines. The program permits personnel, such as plant managers, operators, and maintenance, to optimize the layout since the program presents problems that can exist on preliminary layouts with solutions to optimize the equipment-to-equipment interplay and performances.

In addition to saving time normally associated with a plant layout, there are also savings in expenses. See **auxiliary equipment; fabricating processing type; fabricating startup and shutdown; plant control.**

design, Poisson's ratio in A required constant in engineering analysis for determining the stress and deflection properties of materials (plastics, metals, etc.). When a material is stretched, its cross-sectional area changes as well as its length. Poisson's ratio (ν) is the constant relating these changes in dimensions. It is defined as the ratio of the change in lateral width per unit width to change in axial length per unit length caused by the axial stretching or stressing of a material. It is also the ratio of transverse strain to the corresponding axial strain below the tensile proportional limits. It always falls within the range of 0 to 0.5. A zero value indicates that the specimen would suffer no reduction in diameter or contraction laterally during the elongation but would undergo a reduction in density. A value of 0.5 would indicate that the specimen's volume would remain constant during elongation or as the diameter decreases such as with elastomeric or rubbery material. Plastics range from about 0.3 to 0.4. See **design technology; engineering approach versus practical approach; proportional limit; strain; stress; tensile strength.**

design, polymer See **designing with plastic tailor-made models.**

design, process See **designing processes, with models.**

design process simulator See **process simulator.**

design product size Part size is limited by the available equipment that can handle the size, pressure, part thickness, specific shape, and other design details. Generally, the lower the process pressure, the larger the part that can be produced. With most labor-intensive fabricating methods, such as RP hand lay-up with thermoset plastics, slow process reaction time can be used so that there is virtually no limit on size. A general guide to practical processing thickness limitations based on heat transfer capability through plastics is (in inches) injection molding 0.02 to 0.5; extrusion 0.001 to 1.0; blow molding 0.003 to 0.2; thermoforming 0.002 to 1.0; compression molding 0.05 to 4.0; and foam injection molding 0.1 to 5.0. However, with the proper process controls on materials and equipment, products are produced that range from below to above these figures. See **heat profile; mathematical dimension; melt flow; tolerance.**

design protection The five different methods of protecting your design in the United States are (1) contract (in which the other party agrees not to make, use, etc. without the designer's permission); (2) copyrights (under which protection exists on creation of a design); (3) trade dress (which offers protection when a design is either inherently distinctive or has become distinctive); (4) utility patents (which protect the functional and structural features of a product); and (5) design patents (which protect the ornamental appearance of a product without regard to how it functions). See **computer graphic; legal matter: copyright; legal matter: product liability law; legal matter: trademark.**

design prototype See **prototype, rapid.**

design, reinforced plastic See **reinforced plastic.**

design, reinforcement Fiber behavior in reinforced plastics usually occurs at strains of only 1 to 3%. Designers who are accustomed to designing to yield with a built-in safety factor margin of at least 10% strain might hesitate to use these materials. However, designing with the lower strains is logical and has been used since the 1940s. Data have been developed and used that cover variability in properties, creep, fatigue, and static and dynamic sustained loading. Both short and long fibers are used. The conclusion that short stable fibers will not produce maximum physical properties is not theoretically correct. Both experiment and theory have concluded that with proper adhesion or bond between fibers and resin matrix, maximum properties can basically be achieved by using relatively short stable fibers rather than continuous filament construction. To date, higher performance is overwhelmingly achieved with continuous fibers. Also, the fibers used in reinforced plastics have the important potential of reaching values that are far superior. See **designing with the pseudo-elastic method; directional property; reinforced plastic; ISO-10993 certification.**

design, repair See **pipe, water deterioration; sewer rehabilitation.**

design risk factor See **risk, acceptable.**

design safety factor (SF) A safety factor (SF) or factor of safety (FS) is used with plastics or other materials (metals, aluminum, etc.) to provide for the uncertainties associated with any design, particularly when a new product is involved with no direct historical performance record. No hard and fast rules are available to follow in setting an SF, but the most basic consideration is the consequences of failure. In addition to the basic uncertainties of graphic design, a designer may also have to consider additional conditions, such as (1) variations in material property data (data in a table are the average and do not represent the minimum required in a design), (2) variation in material performance, (3) effect of size in stating material strength properties, (4) type of loading (static, dynamic, etc.), (5) effect of process (stress concentrations, residual stress, etc.), and (6) overall concern of human safety. Also called *factor of ignorance.* See **creep; design-failure theory; fatigue; experience and science; perfection; performance prediction; plastic product failure; production performance; risk, acceptable; safety; strength service factor.**

design, sandwich-construction A popular, high-performance, light-weight, method of increasing stiffness by fabricating special shapes that for certain products provides cost reductions. This design is similar to the I-beam shape, in which the facings (plastics unreinforced or reinforced) correspond to the flanges and the cores (plastic foams, honeycomb structure of plastics, papers, etc.) represent the webs. The facings, also called *skins*, resist axial loads and provide stiffness. The sandwich core stabilizes the facings against buckling or wrinkling under axial compression and provides resistance to shear in bending. See **design, EI theory; coextrusion foam core; moment of inertia; plastic house; sandwich construction.**

design, screw See **screw design.**

design, sealant joint-shape As a joint moves, stresses are imposed on the sealant that are more or less severe depending on the shape of the original joint. The deeper a sealant is in a given joint for a given width, the more neck-in and internal stress occurs in the sealant as the joint opens. There is a greater chance for cohesive failure (adhesive failure) with the deeper joint. A similar problem is involved when a sealant is used in a joint in which there is no breaker strip at the bottom or back of the joint, so that the sealant is in contact with only the face of the joint exposed. This design puts a greater strain on the cohesive strength of the sealant. One method for eliminating the problem is to employ a breaker strip or type of backing that will not restrict or restrain the sealant but will move with it as the joint moves. See **caulking compound; cohesion; neck-in; strain; sealant; stress.**

design, shaftless See **control drive, optimized; drive-system control.**

design shape One of plastics' design advantages is to use both plastic materials and different manufacturing processes to create almost any conceivable shape. Shape designed for a given weight of materials can provide a whole spectrum of strength properties, especially in the most desirable areas of stiffness and bending resistance. With shell structures, plastics can be either singly or doubly curved via the different processes. See **die shape; fabricating process type; product shape; automobile, composite.**

design shrinkage If a plastic part is free to expand and contract with temperature change, then its thermal expansion property is usually of little significance. However, if it is attached to another material having a lower thermal expansion, then movement of the part will be restricted. Temperature change will then result in the development of thermal stresses in the part. The magnitude of the stresses will depend on the temperature change, method of attachment, and relative expansion and modulus characteristics of the two materials at the exposed heat.

Expansion or contraction can be controlled in the plastic by orientation, cross-linking, and adding fillers or reinforcements. Any cross-linking has a substantial effect on thermoplastics. With the amorphous type, expansion is reduced. In a crystalline TP, however, the decreased expansion may be partially offset by the loss of crystallinity. A compounded plastic can be made to match those of the attached material (plastic, steel, etc.). With certain additives, such as graphite filler, the thermal change can be zero or near zero. In fact, during a temperature rise, the plastic can contract rather than expand. Shrinkage can be related to the coefficient of linear thermal expansion. See **amorphous plastic; blow-molding shrinkage; coefficient of linear thermal expansion; crystalline plastic; design, melt-flow Cauchy-Riemann differential equation; melting temperature; molding shrinkage; shrinkage; shrinkage block jig; tolerance and shrinkage.**

design, snap-fit A method of mechanically fastening in which two parts are joined by a properly designed interlocking configuration that is molded directly into the parts. A protrusion molded on one part, such as a hook or bead, is briefly deflected during assembly and engages a depression or undercut molded into the other part. The joint should be stress-free after joining. Cantilever snap-fits are the most common; other types include annular and torsion. See **automotive intake manifold; fastening, mechanical; fit, interference; joining; welding.**

design solution See **problems and solutions.**

design source reduction Designing, manufacturing, purchasing, or using of materials or products to reduce their amount or their toxicity before they enter the municipal solid-waste stream. Because it is intended to reduce pollution and conserve resources, source reduction should not increase net amount or toxicity of waste generated throughout the life of the product. The EPA has established a hierarchy of guidelines for dealing with the solid-waste situation, including source reduction, recycling, waste-to-energy gains, incineration, and landfill. See **energy reclamation; incineration and energy; moment of inertia; recycling; waste, source reduction of.**

design specification Good product design includes good specifications. See **specification; specification and standard limitations; standard; test data and uniform standards.**

design, spring Metal springs are limited to three shapes—the torsion bar, the helical coil, and the flat-shaped leaf spring. Thermoplastics and thermoset plastics can be fabricated into a variety of shapes and used in different environments such as in blood, where spring action is required in a bag for pumping blood. Different plastics satisfy different performance requirements. For example, some provide an excellent damping and fatigue performance. A basically unidirectional, reinforced-plastic aircraft, automobile, or truck spring has variable widths and thicknesses along the length to provide high specific energy-storage capability and weight saving. See **damping; directional property; fatigue; reinforced plastic.**

design, standard A published and proven product design.

design, statistical analysis See **statistical material selection, reliability of; statistical material selection, uncertainty in.**

design, structural See **designing with the pseudo-elastic method.**

design success If plastics are to be used with maximum advantage and with minimum risk of failure, the designer must become familiar and keep up to date with plastic processes and materials and avoid slavishly copying the metal part that the plastic part is suppose to replace. See

computerized knowledge-based engineering; design, innovative; performance prediction; productivity.

design technical cost modeling See **technical cost modeling.**

design technology The prediction of performance in its broadest sense, including all the characteristics and properties of materials that are essential to the process of material selection. To the designer or product engineer, an example of a strict definition of a design property is one that permits the calculating of part dimensions from a stress analysis. However, as with metals, many stresses cannot be accurately analyzed, so designers are forced to rely on properties that correlate with performance. In plastics, these correlative properties, together with those that can be used in design equations, generally are called *engineering properties*. They encompass a variety of stress situations over and above the basic static strength and rigidity, such as impact, fatigue, high and low temperature capability, flammability, chemical resistance, and arc resistance. See **design analysis; design, innovative; design, Poisson's ratio; empirical; computer-aided; definition, art of; moment of inertia; people's challenge; performance prediction; plastics and the future; risk, acceptable; statistical equivalent loading system; stress; technology; test; test data and uniform standards; test analysis, micromechanical; theory.**

design test information See **test.**

design, texturizing See **texturizing.**

design theory and strength of material No fine line separates the theory of elasticity from the methods of strength of materials. The value of one approach over the other depends on the particular application. In most engineering problems, both methods assume homogeneous, isotropic solid, linearly elastic material. Both methods require that equilibrium of forces be satisfied. These conditions being met to a reasonable degree, the elasticity solution would be expected to be superior to the strength of materials. However, an assumed stress distribution may accurately portray the system due to factors such as local yielding, and, in some cases, the strength of materials method may be favorable. See **empirical; moment of inertia; plastic material selection; plastic properties; strengthening plastic mechanism; Staudinger, Hermann; strength of material; theory.**

design toughness See **deformation and toughness.**

design verification (DV) The series of procedures used by the product development group to ensure that a product design output meets its design input. It focuses primarily on the end of the product development cycle. It is routinely understood to mean a thorough testing of the final product to ensure that it is acceptable for shipment to the customers. In the context of design control, however, DV starts when a product's specification or standard has been established and is an ongoing process. The net result of DV is that the final product meets performance requirements with a high degree of accuracy and is safe and effective. According to standards established by ISO-9000, DV should include at least two of the following measures: (1) holding and recording design reviews, (2) undertaking qualification tests and demonstrations, (3) carrying out alternative calculations, and (4) comparing a new design with a similar, proven design. See **fabricating, world-class; performance prediction.**

design vibration See **design energy and motion control.**

design with plastics flowcharts See **World of Plastics Reviews, Fundamentals of Designing with Plastics and Reinforced Plastics.**

design workplace See **ergonomic.**

desizing See **fabric desizing; fiber desizing; fiber finish.**

desktop publishing See **printing, photoengraving.**

desorption The process in which an absorbed material is released from another material. Desorption is the reverse of absorption, adsorption, or both. See **absorption; adsorption; moisture equilibrium.**

destaticization The treating of plastics to minimize their accumulation of static electricity and the amount of dust picked up by the plastics because of such charges. See **antistatic agent; electrostatic charge.**

destructive test A test performed on a part in an attempt to destroy it. It is often performed to determine how much abuse the part can tolerate without failing. See **test; test, nondestructive.**

detergent A substance that reduces the surface tension of water (specifically surface-activated agents that concentrate at the oil-water interfaces), exerts emulsifying action, and thus aids in removing soils. See **alkylate sulfonate, linear; molecule, polar; surface tension; zeolite.**

deterioration A permanent change in the physical properties of a plastic such as evidenced by physical, mechanical, or chemical property losses. See **mechanical property; physical property; test, chemical property.**

deterioration, envenomation The process by which the surface of a plastic close to or in contact with another surface is deteriorated. Softening, discoloration, mottling, crazing, or other effects may occur.

detonation The extremely rapid-shock, self-propagating decomposition of an explosive accompanied by a high pressure-temperature wave that moves at from 1,000 to 9,000 m/s. It may be initiated by mechanical impact, friction, hydraulic explosion, or heat.

detractor See **design constraints.**

development See **plastics and the future; research and development; revolutionary versus evolutionary developments.**

deviation The variation from a specified dimension or design requirement, usually defining the upper and lower limits. The mean deviation (MD) is the average deviation of a series of numbers from their mean. In averaging the deviations, no account is taken of signs, and all deviations whether plus or minus, are treated as positive. Also called the *mean absolute deviation* (MAD) or *average deviation* (AD).

See **accuracy; error, random; machine, coordinate measuring; mean; measurement; molded-material surface measurement.**

deviation accuracy See **accuracy.**

deviation, average See **mean absolute deviation.**

deviation, mean See **mean absolute deviation; mean and standard deviation.**

deviation ratio, standard (SDR) The specific ratio of the average specified outside diameter to the minimum specified wall thickness for outside diameter controlled pipe. This value is derived by adding one to the pertinent number selected from the ANSI Preferred Number Series 10 (Z17.1). As an example, with Series 10 of 5.0, the SDR is 6.0; 10.0 is 11.0; etc. See **pipe.**

deviation, root-mean-square (RMS) A measure of the average size of any measurable item (length of bar, film thickness, pipe thickness, coiled molecule, etc.) that relates to the degree of accuracy per standard deviation measurement. See **deviation, standard.**

deviation, root-mean-square difference (RMSD) A measure of accuracy determined by an equation that includes the number of observations for which the accuracy is determined and the difference between a measured value of a property and its accepted value.

deviation, root-mean-square strain The square root of the mean value of the square of the stress, averaged over one cycle of deformation. For a symmetrical sinusoidal strain, the RMS strain equals the strain amplitude divided by the square root of 2. See **strain; stress.**

deviation, root-mean-square stress The square root of the mean value of the square of the stress, averaged over one cycle of deformation. For a symmetrical sinusoidal stress, the RMS strain equals the stress amplitude divided by the square root of 2. See **strain; stress.**

deviation, root-mean-square voltage Average voltage. It is shown on an alternating, current test meter.

deviation, standard A measure for the dispersion of a series of results around their mean, computed as the positive square root of the variance. The standard deviation is the basis for most statements of precision and may be obtained from an analysis of variance of results of an interlaboratory test program. See **mean and standard deviation; practice; statistical material selection, uncertainty in.**

deviation, standard, measurement (SDM) **1.** A measure of data from the average; the root-mean-square (RMS) of the individual deviation from the average. **2.** A degree of accuracy; the term two-standard-deviation (2 sigma) error can be used. This means that if many tests are performed, 95% of the results would have an error of less than ± 0.25%. Another standard commonly used in laboratory work is the root-mean-square (RMS) accuracy, which is identical for all practical purposes to one-standard-deviation (1 sigma) on a normal distribution, or 68% of the results. When examining the technical specifications, it is important to know whether they are quoting one- or two-standard-deviation accuracies. See **design accuracy; machine, coordinate measuring.**

deviation, standard of sample The sample standard deviation divided by the square root of the number of measurements used in the calculation of the mean. See **mean; sample.**

deviation, variance See **variance.**

device, medical See **legal matter: biomaterial liability bill; medical market; medical packaging.**

device, smart A device with a microcontroller embedded in it. See **auxiliary equipment; intelligence; nanotechnology; plastic, smart.**

devitrification Crystallization in a glass melt that occurs when the melt is too cold. The defects can appear as defects in glass fibers. See **fiberglass.**

devolatilization (DV) The removal of contaminants (in most cases they are volatile relative to their plastic) from the condensed phase by evaporation into a contiguous gas phase. The plastic to be devolatilized may be in the form of a melt or particulate solid. Separation is effected by applying a vacuum or by using inert substances, such as purging with nitrogen gas or steam. See **extruder venting; injection-molding venting; purging; purification; screw decompression zone.**

Two types of DV actions occur: (1) volatile components diffuse to the plastic-vapor interface (called diffusional mass transport), and (2) volatile components evaporate at the interface and are carried away (called *convective mass transport*). If (1) is less than (2), the process is diffusion-controlled. This condition represents most of the plastic devolatilization processes because plastics diffusion contents are usually low.

The important relationship in diffusional mass is Fick's law. It states that in a one-dimensional diffusion, the positive mass flux of component A is related to a negative concentration of ingredients. This law is valid for constant densities and for relatively low concentrations of component A in component B. The term *binary mixture* is used to describe a two-component mixture. A binary diffusivity constant of one component is a binary mixture. The diffusional mass transport is driven by a concentration gradient, as described by Fick's law, which is similar to Fourier's law, which relates heat transport to a temperature gradient, and to Newton's law, which relates momentum transport to a velocity gradient. Because of the similarities among these three laws, many problems in diffusion are described with similar equations. Also several of the dimensionless numbers used in heat-transfer problems are also used in diffusion mass-transfer problems. See **diffusion; heat transfer; reactor technology; volatile content.**

devulcanization See **vulcanization, de-.**

dew/frost-point hygrometer See **hygrometer.**

dew point (DP) The temperature at which vapor begins to deposit as a liquid or condenses on a surface. It represents the temperature at which water vapor must be reduced to obtain saturation vapor pressure—that is, 100% relative humidity. It also applies to a gas that is saturated with respect to a condensable component; it is an accurate indication of the moisture content of a gas. As air is cooled, the amount of water vapor that it can hold decreases. If air is cooled sufficiently, the actual water-vapor pressure becomes equal to the saturation water-vapor pressure, and any further cooling beyond this point will normally result in the condensation of moisture. See **moisture content versus dew point; temperature.**

D-glass See **fiberglass type.**

diagram See **fishbone diagram; graphical database.**

diagram, molding See **molding area diagram; molding volume diagram; processing window.**

diallyl compound See **allyl plastic.**

diallyl phthalate plastic (DAP) A thermoset plastic that is widely used with alkyds in applications such as thermoset polyester-glass fiber prepregs. It has excellent moisture resistance, high service temperature, good retention of electric properties under high temperatures and humidity, product dimensional stability, chemical resistance (except for phenols and oxidizing acids), and good mechanical strength. The nonvolatile stability of the DAP monomer confers good surface hardness. A common example of its use is the imitation-wood-grain, low-pressure laminates used for furniture and wall paneling. They contain 5 to 10wt% DAP. The DAP's major use is in electrical connectors used in communications, computers, aerospace, circuit boards, arc-track-resistant, switch-gear, and so on. Its high thermal resistance permits its use in vapor-phase soldering. See **alkyd plastic; allyl diglycol carbonate plastic; polyester plastic, thermoset.**

dialysis The process of using a semipermeable membrane made of plastics such as nylon and fluoropolymer to stabilize the concentration gradient between a solution on one side and pure solvent on the other side. The kinetic movement of the solute molecules will tend to drive them through the membrane in the direction of lower concentration. However, as a result of osmosis (osmotic-pressure difference), the net movement of the solvent molecules will be in the opposite direction. See **osmosis.**

diamagnetic susceptible See **molecule, diamagnetic susceptible.**

diametrical clearance See **screw and barrel clearance.**

diamond See **carbon.**

diamond finish See **surface finish.**

diaper See **disposable products.**

diaphragm See **reinforced plastic-bag molding.**

diaphragm gate See **mold gate, diaphragm.**

diaphragmming See **oil canning.**

diatomaceous earth A siliceous white powder (kieselguhr) that is used as a filler in plastics to increase their hardness, heat resistance, and dielectric strength. It is an excellent filter and provides special filtration action with the brewing of beer. See **filler.**

dibasic Pertaining to an acid that has two displaceable hydrogen atoms per molecule. See **acid.**

dice cut Plastic cubes of about 2 to 3 mm in size.

dicer A device that cuts (with chopper, notched-knife, ratchet-tooth, etc.) plastic strands or sheets for further processing. Materials such as film, profiles, and reinforced plastic thermoset prepreg materials are cut into different shapes, such as circular pellets, rectangular pellets, and cubes. After a plastic compound has been prepared, it can go through a slit flat die opening and extrude a narrow or wide flat strip or sheet. Roll mills are also used to produce the strip or sheet. Like the strand pelletizer, this strip or sheet is cooled, usually through a water trough. Flat material is pulled by rollers that directs it into the cutting or dicing chamber. As the plastic enters the cutting chamber, size reduction is achieved through the action between rotating knives on a rotor and a stationary bed knife. Design configuration of the knives, strip-fed rate, rotor speed, and the number of rotating knives determine size, configuration, and their output rate. After the strip is diced, they fall through a discharge chute onto a vibrating screen for separating stringers. See **die-face pelletizer; drying; fine; granulator; material, cutting burr-free; fine; pellet; pelletizing; plastic material.**

dichloroethylene A colorless liquid with a pleasant odor. It is used as a solvent for organic compounds and organic synthesis and also in dye extraction, lacquer, and perfume.

dicyandiamide A catalyst for epoxy plastics, a stabilizer in detergents, etc. See **catalyst.**

die A device, usually of steel, having an orifice (opening) with a specific shape or design geometry that it imparts to a plastic melt extrudate pumped from an extruder. The function of the die is to control the shape of the extrudate by delivering melted plastic to the die in an ideal mix at a constant rate, temperature, and pressure. Measurement of these variables is desired and usually carefully performed. The terms *die, tool, mold*, and *cutting die* are virtually synonymous in the sense that they have female or negative cavities through which a molten plastic moves usually under heat and pressure or they are used in other operations such as cutting dies or stamping plastic sheet dies. *Tool* is the term that identifies all these devices, particularly dies and molds. See **machining; tooling.**

die adapter The part of an extrusion die that holds the die block and can be used to reduce complex flow patterns of the melt by providing a streamlining shape. It moves the plastic melt from the plasticator (extruder) to the die. Also called *offset adapter, die feedblock*, or *crosshead adapter.*

die adapter, fish-tail The transition from a round opening block of melt as it exits from the extruder barrel and is then flattened and spread before entering the die.

die adjustment The movement of the die relative to the die pin.

die air vent The passage in a hollow pipe or profile die that permits the movement of air into the interior of the hollow extrudate.

die and pin set A matching bushing and pin dimension that is used to form the extrudate. Also called *die and shaping.*

die, autoflex A sheet die in which the lip opening is controlled by the expansion or contraction of thermal bolts, which, in turn, respond to sheet thickness sensors.

die blade A deformable member that is attached to a die body that determines the orifice slot opening and that is adjusted to produce uniform thickness across a film or sheet that is extruded.

die block The part of an extrusion die that holds the forming bushing and die core.

die, blow molding See **blow molding extruder die; blow molding, extruder-mold.**

die, blown film Dies that are designed to produce circular films that have layflat dimensions from inches (cm) to hundreds of feet (m). See **extruder-blown film; extruder blown film die, coextruded.**

die body The main structure of the die head excluding the bushing and pin.

die-bolt heater A device that expands die bolts usually in sheet extrusion dies to control transverse thickness. It provides an important process-control procedure.

die bushing A tubing die section that forms the outside diameter of the tube. It is usually an adjustable bushing, outside the ring forming wall, at the bottom of the die body, which determines the final orifice outer diameter or surface and shape.

die bushing adjustment The process of moving the die bushing relative to the die pin.

die cart A trolley that supports the die and holds it at the correct height for machine connection.

die casting **1.** The shaping of metal products by forcing a molten metal or alloy under high pressure into a female or negative cavity by means of a hydraulic ram. See **plastic and die-cast metal. 2.** The shaping of plastics that are not melt processable by the more conventional fabricating equipment.

die casting alloy An alloy with melting points sufficiently low so that it can be cast into reusable dies. Commonly used alloys are zinc based or aluminum based. See **mold material.**

die-cast metal See **plastic and die-cast metal.**

die cavity Prior to the melt entering the die orifice, melt flows through a cavity to provide laminar flow of the melt. Different shapes are used, with the streamline type preferred.

die choker bar See **die restrictor bar; extruder sheet choker bar.**

die cleaning See **aerated sand cleaning, hot; cleaning; mold cleaning.**

die, coathanger The popular coathanger die, used for extruded flat sheets and other products, illustrates an important principle in die design. The melt at the edges of the sheet must travel farther through the die than the melt that goes through the center of the sheet. A diagonal melt channel with a triangular dam in the center is an approach to some degree of restricting the direct flow. The principle of built-in restrictions is used to adjust the melt flow in dies. With blow molding and profile dies, the openings require special attention to provide the proper product shape.

The coathanger manifold design can be tuned for a processing window of different flow rate plastics. This manifold is designed by establishing the same resistance to flow across the manifold and land, at various points across the die. Its shape is typically a teardrop that reduces in size from the center to the ends of the die. This reduction in volume reduces residence time in the die and is of particular importance when processing thermally degradable plastics. After the land, the melt flows into a secondary manifold, an area of the flow channel that allows the plastic to move laterally again if required. It also is used to control the total pressure drop of the die in conjunction with the final lip land.

The back line of the coat-hanger manifold is further from the exit of the die at the center than it is on the ends. This could result in a die that will deflect its opening more at the center, causing uneven melt distribution. See **die, multiflow; die, T-slot.**

die coating Protecting materials of construction in metal dies against damage such as corrosion and abrasion by using special metals and applying coatings to their surfaces. See **chrome plating; corrosion resistance; mold cavity coating; tooling coat. 2.** Materials such as wood and metal that act as substrates are extruder coated. The substrates can be in a continuous length or in sectional lengths fed continuously through the extruder die as is done with wire coating.

die, coextruding Many techniques are available for coextrusion, some of them patented and available under license. There are basically the feed-block (single manifold) or the multimanifold dies with a third system that combines the two basic systems. This third system provides processing alternatives as the complexities of coextrusion increase. With the single manifold die the plastics meet (combine surface to surface) and spread to a given web width. In a multimanifold die the plastics are spread to a given web width and then meet slightly upstream from the die lip exit. Because the plastic layers are kept separate until they are fairly close to the die exit, interface deformation and interfacial instability are generally not a problem. This result is due to the fact that there is a limited time the plastics are allowed to flow together so that any temperature differential has a short duration. With proper die designs, flow rate can be adjusted for each melt via the usual fixed or adjustable restrictor bars.

Assuming both basic types have good manifold designs, the multimanifold can process a broader range of melt-flow plastics. No matter which method is used, it is important to maintain the melt heat of each layer above the "freezing" temperature of all layers. If temperatures are not properly set, adhesion between the layers will be poor. The multimanifold die is usually limited by the number of layers. To date this restriction is due to the physical equipment size required. To compensate for this restriction, one or more feed-blocks are used, resulting in more layers of materials. Compatible plastics can flow through a single manifold, reducing any potential problem downstream in the multimanifold. Combinations can be made to provide different laminated designs. However, the final existing-layer thickness distributions can be affected by the amount of die body deflection if the die is not properly designed to take the required loads. Any deflection causes distortion influencing the melt flow channel(s). See **coextrusion; die diverter valve; die, multiflow; extruder-blown film die, coextruded; extruder-blown film die, coextruded-reflective die contractional obligation; legal matter: mold contractional obligation.**

die control See **process control.**

die convergent A die in which the internal channels leading to the orifice are converging; applicable to dies for hollow bodies.

die core See **core.**

die cooling See **baffle; heat pipe.**

die core See **blow-molding extruder core.**

die corrosion See **chrome plating; corrosion; mold-cavity coating.**

die corrugated See **extruder postforming.**

die, crosshead In extrusion, a device designed to extrude the plastic melt at angle, normally 90° to the longitudinal axis of the extruder screw. See **extruder pipe and tubing die; extruder wire and cable die.**

die cutter See **cutter, die.**

die deckle system A system that uses a deckle rod, plate, or dam that is attached to cover each end of a film or coating die orifice and that can be used to reduce the die slot width or to control the edge bead on the web. The plastic to be extruded and the extrusion process determine whether the die can be deckled. Degradable plastics are not used since deckles dam the melt flow, causing stagnated areas where degradation will occur. The most commonly used is an external type that can be bolted to a die half or permitted to slide. External deckles can be designed to adjust manually, driven by power screws or by rack and pinion gears. The disrupted melt flow from behind a conventional external deckle usually causes heavy edges; they prevent good roll contact over the center of the sheet by the polishing rolls and in turn can result in lower sheet gloss. To reduce this undesirable condition, edge beads or internal deckles can be used. The edge bead rod is typically a shaped rod that is inserted into the die stream of the final land. By varying its depth of insertion, the heavy end melt flow can be controlled. See **die face dam.**

die design See **design, die; die efficiency.**

die divergent A die for hollow products in which the internal channels leading to the die orifice are diverging.

die diverter valve A valve that is used to divert melt from one extruder die passage to another. It is used in coextrusion, blow molding, and other dies.

die draw-down ratio The ratio of the thickness of the die opening to the final thickness of the extruded product. See **draw-down ratio; extruder wire and cable die draw-down ratio.**

die drip The carbonized plastic drool that forms on the face of an extrusion die face during the production cycle. If the die face is not kept clean, die drip can solidify, break off, and contaminate the virgin plastic. See **die grooving.**

die, dry sleeve calibration A system that produces precision profile extrusions using a well designed streamline die (with no dead spots or eddy melt-flow patterns occurring), a series of vacuum calipers (similar to a sizing sleeve in a cooling vacuum tank to supply specifically metered vacuum and cooling water to the calipers), air cooling and radiant heating stands to keep the profile straight, a puller meeting the required pulling force at an accurately controlled operating speed, and a reliable cutoff saw and stacking system. See **extruder cooling and takeoff equipment.**

die efficiency The compatibility of the die with the extruded products. If a die is designed for sheet thicknesses of 0.150 to 0.375 in. (3.8 to 9.5 mm), it is extremely difficult for it to extrude 5 mil (0.005 in. or 0.001 mm) film. As there are no universal die designs, running a die beyond its capabilities results in poor gauge control and other problems. If the geometry of the flow channel is optimized for a plastic under a particular set of conditions (heat, flow rate, etc.), a simple change in flow rate or in heat can make the geometry very inefficient. Except for circular dies, it is essentially impossible to obtain a channel geometry that can be used for a relatively wide range of plastics and a wide range of operating conditions. See **design, die.**

die entrance angle The maximum angle at which the melt enters the die land area measured from the center line of the mandrel.

die entry angle The angle of convergence of melt entering the extrusion die lips.

die, extruder See **extruder; extruder barrel-die coupling; extruder pipe and tubing die; extruder wire and cable die.**

die-face dam The brass plates at the end of the die that open to reduce or adjust the width of the extrudate exiting the orifice. See **die deckle system.**

die-face pelletizer A device that uses high-speed knives to cut the extrudate on or near the die face. Several different designs are used: (1) An extruder pumps melt through a straining head into the die. It passes through round holes in its die plate where a wet atmosphere exists. On exiting the plate, a spinning knife blade cuts the extrudate into pellets. The pellet and water slurry is pumped into a dryer, where the pellets separate from the water. Water is reclaimed for repeat use. (2) Very popular is the wet-cut underwater pelletizer. The die face is submerged in a water housing, and the pellets are water quenched followed with a drying cycle. Throughput rates are at least up to 50,000 lb/h (22,700 kg/h). Smaller units are economical to operate as low as 500 lb/h (227 kg/h). (3) The water-spray pelletizer, with a rotating knife, uses a water-jet-spray cooling action as pellets are thrown into a water slurry. Throughput is about 100 to 1,300 lb/h (45 to 590 kg/h). (4) The hot-cut pelletizer has melt go through a multihole die plate. A multiblade cutter slices the plastic in a dry atmosphere and hurls the pellets away from the die at a high speed. Usually the cutter is mounted above the die so that each blade passes separately across the die face and only one blade at a time contacts the die. Pellets are then air or water quenched, followed by drying if water is involved. Throughput is up to at least 15,000 lb/h (6,810 kg/h). (5) The water-ring unit has melt extruded through a die plate and cut into pellets by a concentric rotating knife assembly. Pellets are thrown into a rotating ring of water inside a large hood. After cooling in the water, they are spirally conveyed to be water-separated and then to a drying operation. (6) With the rotating-die unit, a rotating hollow die and stationary knife is used. The die, which looks like a hollow slice from a cylinder, has holes on its periphery. Melt is fed into the die under minimal pressure, and centrifugal force that is generated by the die rotation causes the melt to extrude through the holes. Pellets cut as each strand passes a stationary knife and are flung through a cooling water spray into a drying receiver. See **dicer; pelletizing; plastic material.**

die fan tail An extrusion die of diverging form.

die feedblock A device that directs melt from the extruder to its die.

die, film and sheet thickness The following general classification can be helpful as a guide to film and sheet thickness selection for a die: (1) film dies are generally applicable for thickness of 0.010 in. (0.003 mm) or less; (2) thin gauge sheet dies are normally designed for thickness up to 0.060 in. (0.015 mm); (3) intermediate sheet dies may cover a thickness range of 0.040 to 0.250 in. (0.01 to 0.06 mm); and (4) heavy-gauge sheet dies extrude thickness of 0.080 to 0.500 in. (0.02 to 0.13 mm). Different groups within the industries may have their own thickness definitions. See **extruder film; extruder sheet; optical property.**

die finish See **die coating; polish; surface finish.**

die, fish tail See **extruder barrel adapter.**

die, flat A die with its straight slit opening used in an extrusion film or sheet line. Also called a *slot die.*

die-flow instability See **design, basics-of-flow die; melt-flow defect.**

die gap The distance between the metal faces forming the die opening or orifice.

die grooving Long, narrow grooves or depressions in the cavity surface parallel to its length. It usually is caused by die fouling or by a spot of plastic buildup on the die surface, which effectively changes the shape of its cross-section and extrudate. See **die drip; extrudate.**

die hang-up A problem associated with irregular or uneven flow through a die. It can be caused by dirt, uneven temperature, or poor design of the die (for example, lack of streamlining).

die head The entire structure that is used to manufacture the die.

die head, adjustable A die head whose orifice opening is adjustable.

die head mandrel The center section of the die head about which the melt flows. The mandrel supports the die pin. The sizing element either in a die or in a sizer controls one dimension of the extrudate, usually the inside diameter. Also called *torpedo*. See **mandrel; spreader.**

die head mandrel cooling, internal The tube-sizing system that uses cross-head extrusion with cooled mandrel to size the inside diameter of the tubing. See **extruder pipe and tubing die.**

die head mandrel diverter A die head in which the melt is fed into the side of the die head and diverted around the mandrel by flow guides.

die-head mandrel movement A die head whose mandrel or pin can be moved so as to vary the orifice opening. A structure containing the flow passage that carries the melt to a multiple head.

die head, programmed A die head with provisions for varying the orifice opening at specific points during melt extrusion such as to program the extrudate of a blow-molding parison. As the parison drops, its thickness will vary based on the program setting. See **blow molding, extruder parison programmed control; control actuator; microprocessor control; process control.**

die heater-adapter The part of the die around which a heating element is located.

die heating See **heat pipe.**

die laddering A defective surface finish that is caused by melt fracture in the die. See **melt fracture.**

die land The parallel section of the pin and bushing just before the exit of the die head in the direction of the melt flow. It is vital to shaping the extrudate and providing thickness dimensional control. A very important dimension is the length of the relatively parallel die land. In general, it should be made as long as possible. However, the total resistance of the die should not be increased to the point where excessive power consumption and melt overheating occur. The required land length depends not only on the type and temperature of the thermoplastic melt but also on the flow rate. The deformation of the melt in the entry section of the die invariably causes strains that only gradually decrease with time (relaxation). Usually the target is to allow the melt to relax before leaving the die. Otherwise the product dimensions and the mechanical properties may vary, particularly with rapid cooling.

There have been various basic rules for length of the die land. One states it must be sufficiently long for the residence time of the melt in the die at a mean velocity to be at least equal to the relaxation time. Another relates to long lands as a means to develop sufficient back pressure by using a minimum land of 10 times the die opening or (in the case of rod or tubular dies) one diameter of the die opening. A maximum approach angle for tapered sections is 30°, and many designs incorporate multiple, decreasing-angle sections or radius sections to minimize drag and plastic hold-up time. Die-land length is usually expressed as the ratio between the length of the opening in the flow direction and the die opening, expressed, for example, as 10:1.

die leakage Leaking that can occur in the die seal, end-plate, restrictor bar, and so on. Leakage, particularly in flat dies, can easily damage the product and requires proper design and maintenance to avoid.

dielectric **1.** A nonconductor of electricity that is an insulating material. **2.** The ability of a material to resist the flow of an electric current. In radio-frequency preheating of molding compounds, *dielectric* may refer specifically to the material that is being heated. See **electric; heating, dielectric.**

dielectric absorption An accumulation of electrical charges within the body of an imperfect dielectric material when it is placed in an electric field.

dielectric analysis (DEA) The qualitative or quantitative measurement of a variety of changes in plastic properties induced by exposure to a periodic electric field. These analyses can help determine flow, degree and rate of cure, molecular relaxation, thermal transition, and the dielectric properties of thermoplastic and thermoset plastics, elastomers, reinforced plastics, adhesives, and coatings in their various forms such as solids, liquids, pastes, and films. See **thermal analysis.**

dielectric constant The ratio of the capacitance of an assembly of two electrodes separated solely by a plastics insulating material to its capacitance when the electrodes are separated by air. See **vapor detector, dielectric.**

dielectric constant, complex The pectoral sum of the dielectric constant and the loss factor. See **modulus of elasticity, complex; shear modulus, complex.**

dielectric constant, relative The ratio of change in density arising from an electric field with and without the material present.

dielectric curing See **curing, dielectric; thermoset plastic curing, dielectric monitoring.**

dielectric dissipation factor The ratio of the capacitance of a given configuration of electrodes with the material as the dielectric, to the capacitance of the same electrode configuration with air as a dielectric. Also called *dielectric loss tangent* or *permittivity loss factor.*

dielectric film See **parylene plastic.**

dielectric heating See **heating, dielectric.**

dielectric loss A loss of energy evidenced by the rise in heat of a dielectric placed in an alternating electric field. It is usually observed as a frequency-dependent conductor. See **plastic, nonpolar.**

dielectric-loss angle The difference between 90° and the dielectric-phase angle. Also called the *dielectric-phase difference.* See **dielectric-phase angle; electrical loss angle.**

dielectric-loss factor The product of the dielectric constant and the tangent of the dielectric-loss angle for a material. Also called *dielectric-loss index.*

dielectric-loss index The product of the dielectric constant and the dielectric dissipation factor.

dielectric-loss tangent The difference between 90° and the dielectric-phase angle. Also called *dielectric-phase difference.*

dielectric Maxwell-Wagner effect See **test, dielectric.**

dielectric monitoring The monitoring of the cure of thermoset plastics by tracking the changes in their electrical properties during their fabricating processing. See **dielectrometry; thermoset plastic curing, dielectric monitoring.**

dielectric permittivity See **electrical permittivity.**

dielectric-phase angle The angular difference in phase between the sinusoidal alternating potential difference applied to a dielectric material and the component of the resulting alternating current having the same period as the potential difference. Generally it refers to mechanical and dielectric processes. See **dielectric-loss angle.**

dielectric piezoelectric See **piezoelectric plastic.**

dielectric power factor The cosine of the dielectric-phase angle or sine of the dielectric-loss angle.

dielectric property The tendency for polar groups in a plastic to orient in an electric field. If the plastic is very flexible, or at least if the polar groups are flexible as connected in a chain structure, they will orient easily and quickly. See **orientation.**

dielectric relaxation See **spectroscopy, dielectric relaxation.**

dielectric space charge Polarization from conductor particles in a dielectric.

dielectric spectroscopy See **dielectrometry.**

dielectric strength The property of an insulating material that enables it to withstand electric stress. It is the electric voltage gradient at which an insulating material failure occurs in volts per mil of thickness. See **shell flour.**

dielectric test See **test, dielectric; test, nondestructive electrical.**

dielectrometry Using electrical techniques to measure the changes in loss factor (dissipation) and the capacitance during cure of a thermoset plastic in a reinforced plastic or laminate. Also called *dielectric spectroscopy.* See **curing, dielectric; dielectric monitoring.**

die line A sharp line in the extruded part directly out or in-line of the die; machine direction. A die line can be caused by nicks in the die lips, restrictor bar, melt hang-up, melt build-up on die lips, and so on. See **die parting line; die spider line; directional property, machine; directional property, transverse; weld line.**

die lip, flexible A secondary manifold, following the conventional larger manifold, to equalize pressure without a restrictor bar and with a wedge-shaped rigid front lip and a bolt adjustable flexible upper lip.

die lip heater A heater embedded in the die lip used to control lip temperature and friction characteristics on sheet lines to aid in controlling transverse thickness.

die maintenance Die disassembly should be done only when the die has had sufficient time to heat-soak or at the end of a run so that it is at operating temperature. A temperature of 450°F (232°C) is adequate for most nondegradable plastics. For degradables, cleanup begins immediately after shutdown to prevent corrosion action on the flow surfaces. While the heat is left on, all the bolts are loosened. The heat then is turned off, and all electrical and sensors are removed carefully. While still hot, it is disassembled and thoroughly cleaned with "soft" brass, copper, or aluminum tools. See **maintenance; trouble-shooting.**

die mandrel See **die-head mandrel.**

die manifold A melt distributor. In a center-fed manifold, the melt flow is inline from the extruder and if a core exists in the die, melt distribution around the core is rather uniform. With the side-fed manifold, such as in blow molding, the melt flow is not as uniform, but proper design and enough length to travel through the die allow a certain degree of uniformity to be achieved. The center-fed die with a core, for extruding products such as a pipe, generally has two types of core support. They are the perforated or breaker plate type and the spider type using streamlined cross pin supports. Generally, the breaker plate type is preferred because it keeps the melt flow more uniform. With the side-fed die different designs are used, such as a groove in the core or a longer die land, to produce a more uniform extrudate. Flow or weld lines can develop especially when lower melt index plastics are used with poor die designs. See **blow-molding extruder die; die line.**

die manufacture See **electrical-discharge machine; machining; prototype; tooling.**

die material Special die metals that are usually constructed of medium-carbon alloy steels. The flow surfaces of the die usually have protective coatings such as chrome plating to provide corrosion resistance. With proper chrome plated surfaces, microcracks that may exist are usually covered. The exterior of the die is usually flash chrome plated to prevent rusting. Where chemical attack can be a severe problem (with PVC, etc.), various grades of stainless steels are used with special coatings. Coatings will eventually wear, so it is important that the die be properly recoated by a reliable plater, usually the original die manufacturer. The slightest scratches on the delicate mirror finish on the melt-flow channel orifice surfaces can produce flaws in the extruded products. Great care must be used during their installations, operations, removal, cleaning, and particularly storage. Design goals are to use as few parts as possible and for the parts to be easily lifted for installation, easily disassembled, easily cleaned, and easily reassembled. See **aluminum; automobile, composite; brass; bronze; beryllium copper; corrosion resistance; electroforming; hardening case; iron; kirksite; mold-cavity coating; mold material; photoetching tool steel; tooling coat; zinc.**

Profile, pipe, blown-film, and wire-coating dies are examples of dies generally constructed of hot-rolled steel for low-pressure melt applications. The high-pressure dies can be made of certain steels such as 4140 steel. Chrome plating is generally applied to the flow surfaces, particularly when processing certain plastics such as EVA. Stainless steel is used for any die subject to corrosion. The steel used in the manufacture of a die varies, depending on the requirements of the plastic and application. The available modern tool steels offer properties in numerous combinations. Fortunately, the needs of the vast majority of steel users can be satisfied with a relatively small number of these steels, the most widely used of which have been given the identifying numbers of the American Iron and Steel Institute (AISI). The properties of the die material usually provide (1) wear resistance to provide a long life, (2) toughness to withstand processing and particularly factory handling, (3) high modulus of elasticity so that the die channels do not deform under melt operating pressure and the dies weight, (4) high uniform thermal conductivity, and (5) machinability so that good surface finish can be applied particularly near the die exit. See **chrome plating; iron.**

die melt cross-flow A flow at right angles to the primary flow direction. It can be a source of distortion in the extrudate shape. With proper die design, distortion can at least be minimized.

die melt flow See **design, basics-of-flow die.**

die melt-flow orientation See **orientation, accidental.**

die melt swell See **design, basics-of-flow die.**

die melt tuning Various approaches that are used to adjust melt flow upstream. Different designs of restrictor bars can adjust the flow prior to reaching the die lip.

die, multiflow Special dies with multiflow chambers. For example, Extrusion Dies, Inc. patented the Fast Gap System for automatic altering die-gap settings without the need to reset lip bolts or change the lip. Its Multiflow V Manifold Design prevents the usual nonuniformities and distortions encountered with traditional coathanger manifolds when coextruding plastics with different viscosities. See **die, coathanger; extruder, multiple die.**

die, multiple See **extruder, multiple die.**

diene plastic A plastic that is based on unsaturated hydrocarbons or diolefins having two double bonds. When the double bonds are separated by only a single bond, the diene is called a *conjugated diene*. In an *unconjugated diene*, the double bonds are separated by at least two single bonds.

die, netting See **extruder netting; extruder post-forming; filament-winding netting analysis.**

die orifice The opening in the die that forms the extrudate. Other processing devices that have orifices include the fiber spinneret, which has many openings for melt flows through and drawn out into a plastic extruded shape. See **fiber spinneret.**

die orifice bushing The outer part of the die in its head.

die orifice modulation See **blow molding, extruder parison programmed-control.**

die, oscillating See **extruder blown film gauge distortion.**

die parison See **blow-molding extruder parison.**

die parison swell See **design, basics of flow die.**

die-parting line The lengthwise depression or flash that can occur on the surface of an extruded part. The line can occur where separate metal parts of the die join together to form the die orifice. Also called *spew line.* See **die line; mold-parting line.**

die pin The removable extension of the die mandrel forming the inside wall of the orifice.

die pin and bushing blank The maximum pin size and minimum die bushing size supplied unfinished.

die, pipe See **extruded pipe and tubing die.**

die platen In blow molding, the mold halves are attached to the platens. Also called *plates.* See **clamping platen.**

die plate-out See **plate-out.**

die plating See **chrome plating.**

die polishing See **surface finish.**

die, preengineered A standardized die component that provides exceptional quality control on materials used, quick delivery, interchangeability, and low cost. See **mold, preengineered.**

die pressure The pressure of the melt measured in the die cavity. The pumping pressure required on the melts entering the different designed die heads differs according to melt-flow patterns within the die cavities. The pressure usually ranges as follows: (1) blown and lay-flat films at 2,000 to 6,000 psi (13.8 to 1.3 MPa); (2) cast film, sheet, and pipe at 500 to 4,000 psi (3.5 to 27.6 MPa); (3) wire coating at 1,500 to 8,000 psi (10.3 to 55.1 MPa); and (4) monofilament at 1,000 to 3,000 psi (6.9 to 20.7 MPa). See **pressure.**

die, profile A die that produces complex cross-sections that tend to follow the contour of its orifice. See **extruder profile die.**

die, prototype See **prototype.**

die, pultrusion See **reinforced-plastic pultrusion die.**

die restrictor bar A device that controls melt pressure within the die so that melt exiting the die is rather uniform. Also called *choker bar.* See **extruder sheet choker bar.**

die ring The outside forming wall that determines the final orifice outside diameter and extrudate shape.

die ring, static or dynamic To better control the extrudate wall thickness, particularly in blow molded parisons to reduce product weight without loss of performance, different die rings can be used. A static ring is a thin wall die made from highly flexible steel and surrounded by adjusting bolts that are adjusted to provide the desired shape. Once it is adjusted, it remains in that position during processing unless further manual adjustments are made. A conventional die without a ring requiring a change in shape would generally require the die to be removed, machined, and remounted. The dynamic flexible die ring is continuously adjusted based on its initial setting. Two oppositely located hydraulic cylinders, which can have electronically programmable controlled servo valves, flex the ring. The ring acts like a vertical parison programmer except the wall thickness changes are circumferential rather than internal. See **blow molding, extruder parison programmed-control.**

die, rotary See **extruder blown film gauge distortion.**

die shape Cavities within the dies. Where possible, all dies should be groomed to promote streamlined melt flow and avoid the obvious pitfalls associated with the areas that could cause stagnation. Design faults such as right-angle bends, sharp corners, and sections where flow velocities are diminished are not conducive to streamlined flow and should be avoided. Some complex shapes do not lend themselves to absolute streamlining, and the stability of their plastic melt must be watched much more closely than the melt with a clean flowing die.

Approaches to developing the streamlined shapes range from totally trial-and-error to finite element analysis (FEA). The "trial" method usually involves gradually cutting or removing the die orifice metal. Between cuts an examination is made of the extrudate and the metal cavity surface to check for melt hang-ups, melt burning, streaks, and other stagnating problems. With FEA one can easily determine streamline flow patterns for some simple profiles using appropriate rheological plastic data. FEA is costly but has its place and requires processing knowledge. Both the "trial" and the FEA approaches actually require experience.

Streamlining can provide a variety of advantages: (1) dies can operate at higher outputs; (2) pressure drops are lower and more consistent over a range of melt temperatures and pressures; (3) generally the melt across the extrudate is more uniform, and shape control is enhanced; and (4) production output rates increase where plastics have limited stability and cause hang-ups or degradation going through nonstreamlined dies. See **finite element analysis.**

die, slit See **extruder coating and laminating process.**

die slot See **die, flat; extruder, slot.**

die, special profile Mechanical movement action in a die that is used to extrude different profiles such as tubing or strapping with varying wall thicknesses or perforated wall. It is usually accomplished by converting rotary motion to a linear motion that is used to move or oscillate the mandrel. For certain profiles, such as the perforated tubing, the orifice exit would include a perforated section usually on the mandrel.

die spider The columns that support the mandrel, or torpedo, section in the melt stream that forms the interior of a hollow section. Melt flows over the mandrel. When the die is side fed, the mandrel is anchored into the rear of the die and does not require spider supports. See **mold-gate spider.**

die spider line The support spider posts interfere with the laminar flow of the melt; melt is separated by the spiders. A longer die after the spider location reduces the problem. However, with increased length other problems will develop such as pressure interference. Using streamlined shaped spiders in line with the melt flow significantly reduces the problem. See **die line.**

die, spinneret See **fiber spinneret.**

die storage See **desiccator; mold storage.**

die surface See **surface finish.**

die swell The enlargement of an extrudate over the dimensions of the die orifice through which it is extruded.

die swell ratio The ratio of the outer parison diameter to the outer diameter.

die temperature Melt temperature and pressure in the head are measured by stock thermocouples and pressure transducers. Plus or minus one degree F is typically used in today's control systems. If there is a cold area in the die, the melt flow in that area will be slow, and the result will be thin gauge. A hot area results in more flow and the potential to burn (degradation) the plastic. The die body is usually cored and heated with electric cartridge heaters. See **controller, temperature.**

External heaters, liquids, and vapors are also used to heat the die body. The wattage used to heat a die is determined by the operating temperature and the mass of the die itself. Insulation of the die should be used whenever practical to protect against burns, to eliminate cold spots, and to conserve energy. Die-body cooling, when required, can be done with air or liquid. Heat tubes are also used occasionally to equalize the temperature in the die. Heaters embedded in the die lip can be used to control lip temperature and friction characteristics on sheet lines to aid in controlling transverse thickness. Mechanical control of the lip opening is often used to control thickness.

die, T-slot A manifold design for dies that is used to improve and control the behavior of melts. For example, the basic manifold for a sheet die is a constant cross-section or T-slot design. In all cases, the internal geometry should be streamlined, and care should be taken to avoid dead spots that could lead to melt degradation. The T-slot manifold relies on a large manifold area and a lip long enough to create a large enough pressure drop to force the melt to the ends of the die. This simple manifold design is used when processing low-viscosity plastics that are not thermally sensitive. See **die, coathanger; die restrictor bar.**

die, tubing See **die-head mandrel cooling, internal; extruder pipe and tubing die.**

die, vacuum box Also called *vacuum sizing fixture.* See **vacuum sizing; extruder vacuum box.**

die, wire and cable See **extruder wire and cable die.**

die, wire draw ratio See **extruder wire and cable die draw down ratio.**

differential curve See **thermal analysis; dilatometer.**

differential gravimetric analysis (DGA) A variation of differential thermal analysis in which additional information is obtained by determining the rate of change in weight during the heating process. See **differential thermal analysis; thermal aging, relative thermal index.**

differential scanning calorimetry (DSC) A method of measuring the energy absorbed or produced by monitoring the difference in energy input (energy changes) into the material and a reference material as a function of temperature. Absorption of energy produces an endothermic reaction; production of energy results in an exothermic reaction. Its use includes studying processing behavior of the melting action, degree of crystallization, degree of cure, applied to processes involving a change in heat capacity such as the glass transition, loss of solvents, and so on. See **analytical instrument; calorimeter; cure degree; differential thermal analysis; melting temperature; thermal analysis; x-ray spectroscopy.**

differential thermal analysis (DTA) An analysis technique in which the test specimen and the control specimen are heated simultaneously and the differences in their temperature are monitored. This difference provides information on relative heat capacities, the presence of solvents, and changes in structure such as melting of one component in a plastic, chemical reaction, and so on. It is similar to using a differential scanning calorimeter except that it is capable of operating at higher temperatures [above 730°C (1,346°F)] but with less accuracy. See **differential scanning calorimetry; thermal analysis.**

differential thermocouple See **thermocouple.**

diffraction See **electron scattering; radiation, diffraction.**

diffraction pattern, Fresnel See **Fresnel diffraction pattern.**

diffraction, x-ray See **x-ray diffraction.**

diffusate See **dialysis.**

diffusion The spontaneous material transport that is caused by thermodynamic forces. Particles such as a gas or liquid intermingle with a solid material. If the gas or liquid is absorbed on one side of the material and given off on the other side, this phenomenon is called *permeability*. Diffusion and permeability of a material are not due to holes or pores in the material but are caused and controlled by chemical mechanisms. See **barrier plastic; bonding, diffusion; devolatilization, basics; migration; permeability; sintering.**

diffusion couple An assembly of two materials in such intimate contact that each diffuses into the other.

diffusion, Fick's law See **devolatilization, basics.**

diffusion, molecular See **molecular diffusion.**

diffusion, water vapor See **water-vapor diffusion.**

diffusivity, thermal See **thermal diffusivity.**

difunctional Having two functions.

digestion See **decomposition, digestion.**

digit One of 10 numerals (0 to 9) in the decimal number system. See **decimal number system.**

digital Constituting a digit.

digital imaging As digital technologies begin to emerge in radiography, a century of total dependence on x-ray film is drawing to a close. Digital x-ray detector devices produce x-rays without film. But unlike other digital imaging technologies, such as magnetic resonance imaging and computer-aided tomography, there is as yet no clearly superior way to make digital radiographs. Engineers have available a bewildering array of solid-state x-ray sensors. Even those devices in the mainstream differ markedly. See **computer-aided tomography; x-ray radiograph.**

digital servo drive See **control drive, optimized.**

digital versatile disc (DVD) An injection-molded disc of polycarbonate. DVDs have at least four times as many pits as a compact disc; those pits are shorter and narrower and their tracks are closer together. Special metallizing systems are used. Their molded-in data storage capacity with a 0.6 mm thick optical disc stores gigabytes worth of data. See **compact disc; phonographic record.**

digitized See **computer digitized.**

digit, significant See **computer digit, significant.**

diisocyanate An organic compound containing two reactive isocyanate groups. See **foamed polyurethane; isocyanate.**

dilantic Pertaining to a liquid that resists being moved but is quite fluid at rest; opposite of thixotropic. See **thixotropic.**

dilatant A material with the ability to increase the volume when its shape is changed. This rheological flow characteristic is evidenced by an increase in viscosity with increasing rate of shear. The dilatant fluid, or inverted pseudoplastic, is one whose apparent viscosity increases simultaneously with increasing rate of shear. For example, the act of stirring creates instantly an increase in resistance to stirring. See **pseudoplastic; viscosity, apparent.**

dilatometer A pyncometer that is equipped with instruments to study density as a function of temperature or time. It can measure the thermal expansion or contraction of solids or liquids, polymerization reactions, and the contraction in volume of unsaturated compounds. It basically is a technique in which a dimension of a material under negligible load is measured as a function of temperature while it is subjected to a controlled temperature program. See **temperature measurement; thermal analysis.**

diluent **1.** An additive that reduces the cost of plastics. **2.** An additive that reduces the concentration of an active material to achieve a desirable or beneficial effect, such as thinning and reducing viscosity. **3.** An inert powdered substance added to an elastomer or plastic to increase its volume. Also called *plasticizer* or *extender.* See **organosol diluent; viscosity, dilute-solution.**

diluent, reactive As used in epoxy formulations, a compound containing one or more epoxy groups that function mainly to reduce the viscosity of the mixture. See **epoxy plastic.**

dilute solution See **solution, dilute.**

dilute-solution viscosity See **viscosity, dilute-solution.**

Di Matteo flex test See **test, crack-growth-resistance.**

dimension See **mathematical dimension; design product size.**

dimensional change See **tolerance.**

dimensional eccentricity See **mathematical dimensional eccentricity.**

dimensional property A factor that influences the fabricating of a part. These properties are the behavior of a material interrelated to the processing controls. Some materials and processes provide very close tolerance to the point that they are almost perfect. See **perfection; plastic material and equipment variable; tolerance.**

dimensional stability The ability of a plastic to retain the precise shape and size that it had when it was first produced. This is an important consideration that is usually based on the thermal property for the majority of plastics. It is the temperature above which plastics lose their dimensional stability. For most plastics the main determinant of dimensional stability is their glass transition temperature (T_g). Only with highly crystalline plastics is T_g not a limitation. See **glass transition temperature.**

dimensional tolerance See **zinc.**

dimensioning and tolerancing, geometric (GD&T) A language system of symbols and internationally accepted notation that greatly increases the expressive power of the "drafting" language (ANSI 14.5 M). It includes defining factors such as the desired form for a plastic surface, flatness of a surface, surface profile of an irregular surface, roundness of a surface, and controlling size and form with profile. See **machine, coordinate-measuring; modeling; prototype.**

dimensioning limit A system where only the maximum and minimum dimensions are shown. Thus, the tolerance is the difference between these two dimensions.

dimensionless quantity A value that is expressed only in pure numbers. Examples include the light index of refraction, reflective index, and relative permeability. See **light index of refraction.**

dimension, reference A dimension without a tolerance that is used for information purposes. See **tolerance.**

dimer See **molecule, dimer.**

dimethyl ketone See **acetone.**

dimethyl phthalate A nontoxic, colorless substance with a slightly sweet odor. It has a rather high volatility and is used principally as a plasticizer.

dimple See **sink mark.**

dinnerware, decorative See **coating, in-mold decorating, labeling.**

dioctyl phthalate (DOP) A pale, viscous liquid that boils at 384°C and is insoluble in water. It is used as a plasticizer for plastics that include acrylates, vinyls, and cellulosics. See **plasticizer.**

dioctyl sebacate (DOS) A straw-colored liquid that is water-insoluble and boils at 248°C. It is used as a plasticizer for plastics that include vinyls, cellulosics, and styrenes. See **plasticizer.**

dioxin A toxic substance that is produced as an emission generated by burning different types of trash. For example, polyvinyl chloride plastic produces dioxin, but according to EPA reports, during incineration the emission generated is far below the maximum requirement. The EPA estimates that less than 1% of 3,000 grams are emitted annually throughout the United States. The agency's most recent dioxin source inventory shows that the most dioxin comes from municipal waste incinerators, backyard trash burning, and landfill and forest fires. Independent international scientific experts review the test results. All the dioxins are a class of toxic organic compounds that may be found in gas released when carbon compounds, such as in waste refuse, are not burned completely. See **hazard; incineration; polyvinyl chloride plastic; vinyl composition tile; vinyl seagoing bag.**

dip blow molding See **blow molding, dip and displacement; blow molding, stretched operation specialty.**

dip casting See **casting, dip.**

dip coating See **coating, dip.**

dip forming See **forming, dip.**

diphenyl oxide plastic A thermoset plastic that is based on phenyl oxide and that possesses excellent handling properties and heat resistance.

dip molding See **blow molding, dip and displacement; forming, dip.**

direct cost See **cost, direct and indirect.**

directional fabric See **fabric, nonwoven; fabric, woven.**

directional property A product property that is dependent on the material of construction's direction or orientation. Included are materials such as oriented film, pressure pipe, support beams, fabrics, laminates, reinforced plastics, and so on. See **World of Plastics Review, Basics and Overviews of Fabricating Processes (fig. 34); birefringence; calendering grain; design, geodesic; directional property, unidirectional; filament winding, circumferential; molding, isostatic; strain, axial.**

directional property, abscissas The horizontal direction in a diagram or curve. See **directional property, ordinate; stress-strain curve; x-axis; x-y recorder.**

directional property, anisotropic Exhibiting different properties when tested along axes in different directions. See **birefringence.**

directional property, balanced A material that has equal properties in the warp and filled directions. Also called the *machine (warp)* and *transverse (filled) directions.*

directional property, biaxial A material that has two major axes (horizontal and vertical at 90° to each other) having the highest properties. They could be equal as in a balanced material. Also called *bidirectional property.* See **orientation, biaxial.**

directional property, coordinated A reference coordinate system that is used to describe the properties in the direction of the principal axes (x and y). See **x-axis; y-axis.**

directional property, crosswise **1.** Being oriented at 0° and 90° and providing equal highest strengths only in those directions; designated high-strength directional properties in the lengthwise direction and at right angle to the lengthwise direction (transverse direction). Also called *bidirectional* or *cross-plied laminate.* **2.** The cross-the-machine direction of a material/product.

directional property, isotropic Having uniform properties in all directions in the plane of the material (x-y directions). See **x-axis; y-axis.**

directional property, isotropic, non- Having properties that are different in the different directions along the flat plane. Anisotropic exhibits different properties in response to stresses applied along axes in different directions.

directional property, isotropic transversely A special case of orthotropy in which the properties are identical in two orthotropic (or a single plane) dimensions but not the third; having identical properties in both transverse directions but not in the longitudinal direction.

directional property, lead See **lead.**

directional property, machine Product output in the machine direction; 90° to the transverse direction. Materials such as sheet being extruded or reinforced plastic being pultruded are exiting in the machine in-line direction where the direction follows the flow of the plastic from the die. At 90° to this direction is the transverse or crosswise direction. Also called *lengthwise direction.* See **directional property, transverse.**

directional property, molecular orientation See **orientation, balance; orientation, biaxial; orientation, uniaxial.**

directional property, nonaxisymmetric See **blow molding, extruder three-dimensional.**

directional property, ordinate The vertical direction in a diagram. See **directional property, abscissa.**

directional property, oriented A directional property that can exist in a material such as oriented film, reinforced plastic, or composite construction. See **composite; orientation; reinforced plastic.**

directional property, orthotropic Having three mutually perpendicular x-y-z planes of elastic symmetry. See **x-axis; y-axis; z-axis.**

directional property, parallel Having layers of materials such as oriented film or fabric that are all aligned and stacked in the same position as they were on their respective roll. See **sheet, laminated; laminate; reinforced plastic.**

directional property, planar Lying essentially in a single plane.

directional property, quadraxially A four-directional layer. See **automobile, composite.**

directional property, quasi-isotropic An approximation of an isotropic construction by orientation of plies in several or more directions.

directional property, rhombohedral Having three equal axes with the included angles equal to each other but not equal to 90°.

directional property, symmetrical A stacking sequence of plies below its midplane and a mirror image of the stacking sequence above the midplane.

directional property, tetragonal Having three mutu-

ally perpendicular axes, two equal in length and unequal to the third axis.
directional property, transverse Refers to product output at 90° to the machine direction. Materials such as flat sheet, film, or pipe being extruded basically are exiting in the machine inline direction with the transverse at 90° to this direction. Also called *crosswise direction*. See **directional property, machine.**
directional property, uniaxial load A condition where a material is stressed in only one direction along the axis or centerline of a component part.
directional property, uniaxial state of stress A state of stress in which two of the principle stresses are zero. See **x-axis.**
directional property, unidirectional A material where all the strengths are substantially all oriented in one direction. See **bamboo.**
directional, unsymmetrical Having an arbitrary stacking sequence without midplane symmetry. See **stress-strain curve; x-y recorder.**
directory See **government contract directory; test laboratories, worldwide approval of.**
disadvantage of plastic See **plastic advantages and disadvantages; plastic myth and fact.**
disassembly See **assembly; design disassembly.**
disaster exercise See **training crisis.**
disbond See **adhesive, disbonded.**
disc, computer See **compact disc.**
disc, fail-safe rupture See **barrel fail-safe rupture disc.**
disc flow test See **test, thermoset flow.**
discoloration A change from the original color, often caused by overheating, light exposure, irradiation, or chemical attack. See **colorant.**
dished See **failure, dished.**
disinfectant A substance used on inanimate (plastic, etc.) products that destroys harmful microorganisms or inhibits their activity.
disk, optical See **compact disc.**
disk reinforcement See **reinforcement, disk.**
disk safety See **plasticator safety.**
dispersing agent A substance that promotes the separation of fine particles in an emulsion or suspension. See **suspension.**
dispersion **1.** Finely divided liquids or particles (powders) of a plastic held in suspension in another material. See **aerosol; foam; emulsion; mixer, paddle-agitator; organosol; plastisol.** **2.** The difference in index of refraction. See **light index of refraction.** **3.** The phenomenon of varying speed of transmission of electronic waves depending on their frequency.
dispersion coating See **coating, dispersion.**
dispersion, plastic See **plastic dispersion.**
dispersion plug See **injection-molding nozzle-plate dispersion plug.**
dispersion, vinyl See **organosol; plastisol.**
dispersive mixer See **mixing, dispersive.**
disposable products Products, such as food service utensils, medical devices, towels, and containers, that are intended to be used only once. Disposable plastic diapers account for 1 to 2 vol% of waste in the United States.
dissipation factor See **electrical dissipation factor; modulus, dissipation factor.**
dissociation **1.** In leak testing, the breakdown of a substance into two or more constituents. See **container leakage.** **2.** As applied to heterogeneous equilibrium, the transformation of one phase into two or more new phases, all of different composition.
distillation A process of evaporation of a liquid to a vapor and the vapor then condensed to a liquid whereby the various fractions of liquids may be separated or purified. The liquid matter being vaporized is called the *charge* or *distilland;* the *distillate* refers to the liquid that is condensed. See **chemical distillation; rectification; strip.**
distillation, atmospheric A distillation operation that is conducted at atmospheric pressure, in contrast to vacuum distillation or pressure distillation.
distillation, batch A distillation where the entire batch of liquid feed is placed into a still at the beginning of the operation, in contrast to continuous distillation where liquid is fed continuously into the still.
distillation, destructive The distillation of substances that is accompanied by their decomposition. For example, with coal, oil, and gas, raw materials are produced for the plastics industry.
distillation fraction A part of a liquid mixture that boils within a given range of temperature and that is collected separately on condensation. For example, oil is divided into many fractions by distillation in the refinery. This process is based on the differing boiling points of the component liquids of the mixture. See **oil.**
distillation, fractional A procedure for separating liquid components of a solution that is based on their different boiling points.
distillation, molecular See **molecular distillation.**
distillation unit See **retort.**
distillation, vacuum Liquid distillation under reduced, less than atmospheric, pressure. It is used to lower boiling temperatures and lessen the risk of thermal degradation during distillation. Also called *reduced-pressure distillation.*
distillation, vapor rate of The upward flow rate of vapor through a distillation column.
distortion **1.** In a reinforced plastic, the displacement of fibers, especially at the radii, relative to the idealized location due to fiber movement during lay-up or cure. **2.** In a fabric, the displacement of a fill fiber from the 90° angle, or at right angle, relative to the warp fiber. **3.** The product of a different shape from that required. It is generally apparent after processing. However, a warped situation can occur after processing if internal stress relaxation occurs after a short or long period of time. Accelerating relaxation is a product of exposure to heat. See **design shape; failure, domed; product shape.** **4.** Regarding optics, an aberration of lens systems where axial and mar-

ginal magnifications are unequal. It is any apparent alteration of the geometric pattern of an object when seen either through a plastic or as a reflection from a plastic surface. See **optical distortion value.**

distortion temperature See **annealing; deflection temperature under load versus crystallinity; test; test, heat distortion point.**

distributive mixer See **mixing, distributive.**

doctor blade A straight (usually) steel blade that is used to spread thin films of plastics for use in hot melt adhesives, reinforced plastic prepregs, coatings to substrates, and so on. Also called a *doctor bar, doctor knife,* or *paste metering blade.* See **adhesive; coating; paste; reinforced-plastic prepreg.**

doctor roll **1.** A roll that operates at a different speed or in an opposite direction as compared to the primary roll of a coating machine, thus regulating the uniformity and thickness of the material on the roll before it is applied to the substrate. See **extruded coating and lamination process.** **2.** A device for regulating the amount of plastic or liquid adhesive on the rollers of a spreader or impregnator. **3.** See **extruder roll, spreader/expander.**

documentation online See **computerized electronic document and retrieval system.**

dodecene See **propylene tetramer.**

doff See **material doff.**

dog skin See **orange peel.**

doily See **filament winding doily.**

dolly A low platform or structure mounted on wheels or casters that is designed primarily for moving bulky loads (materials, molds, dies, products, etc.) for short distances.

dolomite See **filler, dolomite.**

Dominick A 1962 project conducted by the U.S. Department of Defense and the Atomic Energy Commission that involved a series of nuclear tests in the Pacific and evaluated materials (plastics, steel, aluminum, concrete, wood, etc.). Also called *Domenic, Domenico,* and *Dominique.* See **definition.**

dopant **1.** A material that is added to a plastic to change a physical property. See **additive.** **2.** A chemical element that is incorporated in trace amounts in a semiconductor crystal to establish its conductivity and resistivity. See **plastic, electrically conductive.**

dope **1.** A solution that is used to strengthen, color, or tighten materials such as fabric. **2.** A trace of impurity introduced into ultrapure crystals to obtain desired properties, particularly electrical properties. **3.** A combustible, such as sulfur, starch, or wood pulp, that is used in "straight" dynamite.

doppler effect See **electronic doppler effect.**

doser A device that meters or doses a measured amount of plastics or additives into a mixer, plasticator, and so on. Also called *dosing.*

dosimeter See **radiation dosimeter.**

dosing A measured quantity of plastics or additives that is added during any processing.

double-daylight molding See **injection molding, double-daylight.**

doubler **1.** A localized area of extra plastic (ribs, etc.) that provides stiffness and strength for fastening or abrupt load transfer. **2.** See **filament-winding doubler.**

double-screw extruder See **extruder, twin-screw.**

double-shot molding See **molding, double-shot.**

double-wave mixing screw See **screw mixing, double-wave.**

dough A heavy, doughlike compound such as a bulk molding compound (BMC). BMC is fiber reinforced (usually glass fiber) with a B-stage thermoset polyester plastic. Also called *dough molding compound* (DMC). See **A-B-C stages; blender, dough; mixer, paddle-agitator; polyester plastic, thermoset.**

dough molding compound See **bulk molding compound; reinforced-plastic bulk molding compound.**

downstream equipment See **auxiliary equipment.**

downstream line See **processing in-line; processing line, downstream.**

downtime See **processing-line downtime; processing-line uptime.**

downtime line See **processing-line downtime.**

downstream The portion of a fabricating line that has exited the main processing equipment such as an extruder or an injection-molding machine. See **auxiliary equipment; fabricating process; upstream.**

draft See **mold-cavity draft.**

drape The ability of a plastic film, fabric, sheet molding compound, prepreg, and so on to conform to a contoured surface.

drape forming See **thermoforming, drape.**

draw **1.** The act of gradually reducing the sheet, rod diameter, or other shape of a material by stretching or pulling it through perforations of diminishing size in a series of rollers or plates. They may be cold-drawn (without heat) or hot-drawn (heated to their softening point). Also called *stretching* or *drawing.* See **orientation; forming.** **2.** A measure of the depth of a molding, particularly a formed part. See **thermoforming.**

draw-down ratio The degree of stretching of a plastic melt during processing. Also called *draw ratio.* See **blow molding, extruder parison draw-down; die draw-down ratio; extruder draw-down; extruder wire and cable die draw-down ratio; forming, stretch and draw ratios for pressure.**

drawing See **forming, stretch.**

drawing centerline The axis around which character elements are located for letters, numerals, symbols, diagrams, and so on.

drawing cold See **forming, cold-drawing.**

drawing, fiber See **fiber drawing.**

draw resonance See **resonance, draw.**

drive-motor control A hydraulic or electric (direct-current and alternating-current) motor drive is used to provide rotary or linear movement of equipment such as extruders, injection-molding machines, calendering rolls, in-line pullers, turret wind-ups, and many more. For example, with a plasticator, the screw is turned at the required rotating speed resulting in the melt moving forward at a prescribed rate of output. The drive also provides the required amount of torque to the shank of the screw. Various drive design systems are used to meet performance requirements at the lowest cost. The low to high force that is required to melt a plastic and meet output requirements dictates the torque needed in the machine.

DC motor drives have always offered high torque at all speeds and exact control of motion speed. AC induction motors have reliably converted electricity into rotary power for many years, and recently adjustable-frequency controls add variable-speed capability. While AC motors were originally relegated to relatively simple tasks, such as varying the flow rates of fans or pumps, advances in both motor and control technologies have allowed their use in higher performance operations. They are reliable sources of fixed-speed and variable-speed rotating power. Electric drives with appropriate closed-loop control operate only when required. However, to avoid unsuccessful applications, it is important to properly match the load, motor, and controller.

With the exception of the drive for the plasticizing unit in injection-molding machines, movements are all linear. The variable AC servomotors or brushless drives can provide various methods for transforming rotational motions into linear motions. They include a lead-screw, ball-screw, as well as rack and pinion. Force and speed drive systems are optimally matched to the requirements of each individual axis of motion. See **computer analog-to-digital converter; control drive, optimized; electric motor; injection molding machine down-sizing; injection molding machine drive system; injection molding machine electrical operation; injection molding machine hydraulic operation; injection molding machine screw drive; motion-control system; repeatability; servo control; servo-control-drive reliability.**

drool **1.** The melt that leaks from an injection-molding machine nozzle because it has been damaged, or not properly aligned. **2.** The creation of die drips on the face of an extruder die. See **die drip.**

drop weight test See **test, dart-drop impact.**

drug application The use by the pharmaceutical industry of different plastics in different drugs as carriers and to adjust concentrations or control release. It also refers to different types of containers for handling and shipping. See **anilene; biodegradable waste; coating, microencapsulation; design, medical-product; medical-device packaging clarity.**

drug biological activity See **biological activity.**

drug, controlled-delivery The delivery system in the human body provides an effective release of pharmaceutical drugs (also flavors, etc.). The drug can be imbedded or encased in a reservoir, from which it gradually is released using a degradable plastic. See **biological activity; coating, microencapsulation; medical chronotherapeutic; packaging, breathable-film.**

drug packaging See **medical seal and closure.**

drug tumbling See **tumbling, drum.**

dry blasting See **cleaning, abrasion.**

dry-blend See **compound, dry-blend.**

dry-bulb temperature See **temperature, dry-bulb.**

dry coating See **powder coating.**

dry color See **coloring, dry.**

dry cure See **extruder wire and cable process, dry-cure.**

dryer A device that is used to dry plastics before processing. Several styles are used, such as ovens, microwaves, hot-air desiccant beds, and refrigeration types.

dryer, ultraviolet A dryer that is used in certain processes (cure coatings, high speed printing presses, etc.) to solve air-emission problems to clean air in and around plants.

dry ice See **ice, dry.**

drying All plastics, to some degree, are influenced by the amount of moisture or water they contain before processing. With minimal amounts in many plastics, mechanical, physical, electrical, aesthetic, and other properties may be affected or may be of no consequence. However, there are certain plastics that, when compounded with certain additives such as color, could have devastating results. Day-to-night temperature changes are an example of how moisture contamination can be a source of problems if not adequately eliminated when plastic materials are exposed to the air, otherwise it has an accumulative effect. See **drying operation, hygroscopic plastic; hydrolysis; plastic, hygroscopic; Raoult's law; test specimen, moisture and drying; troubleshooting optical sheet; venting feeder; water.**

drying agent A substance that is used to accelerate the drying of plastic coating, paints, varnishes, printing inks, and so on by catalyzing the oxidation of the material. See **aluminum stearate; desiccant; molecular sieve.**

drying, capillary The outer surface of a porous solid has pore entrances of various sizes. As surface liquid is evaporated during constant-rate drying, a liquid meniscus forms across each pore entrance. Interfacial tension between the liquid and solid occurs. These forces draw liquid from the interior to the outer surface. See **capillarity.**

drying, constant-rate Drying that proceeds by diffusion of vapor from a wet surface through a gas film into the environment.

drying, critical moisture content The average material moisture content at the end of the constant-rate drying period, which is a function of material properties, the constant-rate of drying, and particle size.

drying desiccant See **desiccant.**

drying diffusion See **diffusion.**

drying, dry Curing at air temperature without the application of heat and pressure.

drying, equilibrium moisture content See **moisture-content equilibrium.**

drying, hopper See **hopper dryer.**

drying hygroscopic plastic See **drying operation, hygroscopic plastic; plastic, hygroscopic.**

drying instrument, measuring See **hygrometer.**

drying, mechanical Using mechanical heat-convection hot-air dryers. They can be adequate for some plastics but are not satisfactory for hygroscopic plastics.

drying mechanism Although it is sometimes possible to select a suitable drying method simply by evaluating variables such as humidities and temperatures when removing unbound moisture, many plastic drying processes involve removal of bound moisture retained in capillaries among fine particles or moisture actually dissolved in the plastic. A knowledge of internal liquid and vapor mass-transfer mechanisms applies. Measuring drying-rate behavior under controlled conditions best identifies these mechanisms. A change in material handling method or any operating variable, such as heating rate, may affect mass transfer.

drying, nonhygroscopic plastic See **drying operation, nonhygroscopic plastic.**

drying monomer and polymer Volatile liquid is separated from a solid or semisolid material by vaporization. The drying of monomers involves the removal of moisture or other volatiles from fluids. When drying gases, condensable vapors are separated from noncondensable gases by cooling below the dew points of the condensable fractions, vapor adsorption on solid desiccant liquids, or gas compression and cooling. Polymer dryings are employed to separate the saleable product from the reaction process. Drying is usually necessary following the three common polymerization processes of solution, suspension, and emulsion.

drying operation During the drying process at ambient temperature and 50% relative humidity, the vapor pressure of water outside a plastic is greater than within. Moisture migrates into the plastic, increasing its moisture content until a state of equilibrium exists inside and outside the plastic. But conditions are very different inside a drying hopper with a controlled environment. At a temperature of 350°F (170°C) and −40°F (−19.43°C) dew point, the vapor pressure of the water inside the plastic is much greater than the vapor pressure of the water in the surrounding area. The result is that moisture migrates out of the plastic and into the surrounding air stream, where it is carried away to the desiccant bed of the dryer. Before drying can begin, a wet material must be heated to such a temperature that the vapor pressure of the liquid content exceeds the partial pressure of the corresponding vapor in the surrounding atmosphere. Different devices such as a psychometric chart can conveniently study the effect of the atmospheric vapor content on the rate of the dryer as well as the effect of the material temperature. It plots moisture content of dry-bulb, wet-bulb, or saturation temperature and enthalpy at saturation.

First, the plastic's moisture content limit is determined. Next, the procedure that will be used in determining water content, such as weighing, drying, and/or reweighing, is determined. These procedures have definite limitations. Fast automatic analyzers, suitable for use with a wide variety of plastic systems, are available that provide quick and accurate data for obtaining the in-plant moisture control of plastics.

drying operation, hygroscopic plastic Drying or keeping moisture content at designated low levels is important, particularly for hygroscopic resin types where moisture is on the surface and particularly collected internally. They have to be dry prior to processing. Usually the moisture content is >0.02wt%. In practice, a drying heat 30°C below the softening heat has proved successful in preventing caking of the plastic in a dryer. Drying time varies in the range of 2 to 4 h, depending on moisture content. As a rule of thumb, the drying air should have a dew point of −30°F (−34°C) and the capability of being heated up to 250°F (121°C). It takes about 1 ft^3 min^{-1} of plastic processed when using a desiccant dryer. The pressure drop through the bed should be less than 1 mm H_2O per mm of bed height. Simple tray dryers or mechanical convection, hot-air dryers, while adequate for certain plastics, are incapable of removing enough water for the proper processing of hygroscopic plastics, particularly during periods of high humidity.

Hygroscopic plastics are commonly passed through dehumidifying hopper dryers before entering a screw plasticator. However, except where extremely expensive protective measures are taken, the drying may be inadequate, or the moisture regained may be too rapid to avoid product defects unless barrel venting is provided. To ensure proper drying for "delicate" parts such as lenses and compact disks, the combination of drying the plastics and using vented extruders provides a double check. However, just using vented extruders can be suitable.

Plastic usage for a given process should be measured to determine how much plastic should be loaded into the hopper. Usually the hopper should hold enough dried plastic for ½ to 1 hour's production. This action is taken so as to prevent storage in the hopper for any length of time, eliminating potential moisture contamination from the surrounding atmospheric area. Care should be taken to ensure that hygroscopic plastics are in an unheated hopper for no more than ½ to 1 hr, or as specified by the material supplier (and/or experience). See **hydrolysis; injection-molding venting; moisture analyzer; plastic, hygroscopic; screw, venting; troubleshooting optical sheet; venting.**

drying operation, nonhygroscopic plastic Drying surface moisture can be accomplished by simply passing warm air over the material. Moisture leaves the plastic in favor of the warm air resulting in dry plastic. The amount of water must be limited or processing can be destructive.

drying, pre- The process of drying a plastic material to remove moisture prior to processing operations.

drying shrinkage The shrinkage related to drying is the contraction of a body during the drying process, expressed as a linear percent of the original length or volume percent of the original volume. See **shrinkage.**

dry layup See **reinforced plastic layup, dry.**

dry operation See **hydrolysis.**

dry spinning See **fiber processing, spinning, dry.**

dry strength See **adhesive dry strength.**

dry winding See **filament winding, dry winding.**

ductile erosion behavior See **erosion, ductile behavior.**

ductile fatigue See **fatigue ductility.**

ductile fracture See **fracture ductility.**

ductile-to-brittle transition temperature See **molecular weight, toughness, and temperature.**

ductility **1.** The amount of strain that a material can withstand before fracture. See **fracture; metal fracture.** **2.** The extent to which a solid plastic can be drawn into a thinner cross-section without fracturing or breaking. See **malleability.** **3.** See **deformation, plastic; fatigue ductility; orientation; wire wrapping diameter.**

Dulmage mixing screw See **screw mixing, Dulmage.**

dumbbell specimen See **specimen, dumbbell.**

dumping **1.** The disposal of waste material. **2.** The delivery of material imports into a country at a low price to sell at a depressed price because of excess supply or new-market possibilities.

durable goods Products with a relatively long useful life without significant deterioration, if any at all. See **nondurable goods.**

durometer See **hardness, durometer.**

dust Particulates that are capable of temporary suspension in air or other gases that can be collected by various methods. See **calcium chloride; cleanroom.**

dust collection, bag-filter Dust-collecting equipment (bag-house) composed of large cotton or nylon bags assembled in a heavy frame or housing. The bags may be as much as 10 ft (3.05 m) high. The discharge hopper is located beneath the bag. A suction or blower system forces dust-laden air through an inlet port on one side of the frame. On entering the bags, dust is deposited on the bags. A motor-driven shaker mechanism agitates the bags periodically, dislodging the accumulated layers of dust, which falls through the discharge hopper. See **dust collection, cyclone.**

dust collection, bag-house A series of bag filters. Some installations can have over 300 bags.

dust collection, cyclone A cylindrical chamber with the lower portion tapered to fit into a cone-shaped receptacle placed below it. Dust-laden air enters through a vertical slotlike section in the upper wall of the chamber at the rate of at least 100 ft/s (31 m/s). Since the particles enter at a tangent, they whirl in a circular or cyclone path within the chamber. The centrifugal force exerted on the particles is proportional to their weight and to the square of their velocity. The particles slide along the wall and gradually circulate down into the conical receptor while clean air escapes through a central pipe at the bottom. The dust accumulates in the cone and is discharged at intervals or continuously. Particles as small as 10 microns can be removed.

dusting agent A powdery solid that is used as an adherent or release agent. It is used to release molded parts, keep film from adhering, and so on. See **additive, slip; antiblocking agent; lubricant; zinc stearate.**

dust, industrial Finely divided solid particles may (1) damage personnel when they are inhaled or infect skin, (2) constitute a fire hazard, (3) damage the plastic products being fabricated, and (4) damage the processing equipment. There are generally different classes of particle suspensions that are 10 microns or less in diameter, though sizes up to 50 microns can be present. Such dust includes metallic particles, additives and fillers (talc, wood, glass, etc.), and organic matter (chemicals, coal, etc.). See **safety.**

dust, marble See **calcium carbonate.**

dwell **1.** In filament winding, the time that the transverse mechanism is stationary while the mandrel continues to rotate to the appropriate point for the traverse to begin a new pass. **2.** With autoclave curing, an intermediate step in which the thermoset plastic is held at a temperature below the cure temperature for a specified period of time to produce the desired degree of staging. See **A-B-C stages.**

dwell pause See **mold breathing.**

dye A synthetic or natural organic chemical that is soluble in most common solvents and goes through an application process that, at least temporarily, destroys any crystal structure of the colored substances. It is characterized by good transparency, high tinctorial strength, and low specific gravity. See **anilene; colorant; crocking; pigment; porosity.**

dye crocking See **crocking.**

dye extraction See **dichloroethylene.**

dyeing, Witt theory of A theory of the mechanisms of dyeing that states that all colored organic compounds, called *chromogens*, contain certain unsaturated chromophoric groups that are responsible for the color, and if these compounds also contain certain auxochromic groups, they possess dyeing properties.

dye, solvent soluble A dye from a group of widely different chemical compositions that often possess excellent heat stability, especially in the less chemically reactive plastics such as polystyrene, and find wide applications in the production of transparent plastics.

dye toner A dye that is used to develop a particular color characteristic (blueness, whiteness, etc.) to either clear or pigmented plastics. It is used in imaging material and some off-press proofing printing systems and in inks and dyes used to tone printing inks, especially black. It is an organic pigment that does not contain inorganics. See **pigment; printing.**

dye transfer, sublimable Dye transfer resembles hot stamping, but instead of a foil, a paper liner printed with sublimable dyes is used. These dyes sublime on the application of heat and are transferred to the plastic. The pattern is not deposited on the plastic surface but diffuses into the plastic providing an abrasive resistant image. However, the diffusion dye can give a slightly blurred image. See **decal; printing; sublimation.**

dye, transparent See **colorant.**

dynamic A branch of mechanics that deals with forces and their relation primarily to motion and also to equilibrium of bodies. Variation and contrast in force exist, including their density. See **elastomer; kinetic; neoprene elastomer; resilience; solution, saturated.**

dynamic analysis The study of a design under changing internal or external conditions. It can include static analysis, linear and nonlinear. See **designing with the pseudo-elastic method; test data and uniform standards.**

dynamic equilibrium See **equilibrium.**

dynamic fatigue Fatigue that occurs under a load that is varying, usually periodically and often sinusoidal. The lower the loading stress, the more loading cycles that are needed for failure, or *fatigue life.* As the amplitude of the applied stress is lowered, a value is reached (the fatigue limit) below which the material does not fail even after a finite number of cycles. The most common mode of deformation is flexure. As the temperature increases, the time to failure decreases. Under the same conditions of temperature and frequency, when the plastic shows high loss of mechanical energy, temperature rise in the material can occur. See **design-failure theory; fatigue.**

dynamic loading See **design energy and motion control; load, dynamic; modulus, dissipation factor.**

dynamic mechanical analysis, alpha loss peak In dynamic mechanical analysis or dielectric analysis, the first peak (α) in the damping curve below the melt temperature, in order of decreasing temperature or increasing frequency. See **damping.**

dynamic mechanical damping beta loss peak In dynamic or dielectric measurement of the β loss peak, the second peak in the damping curve below the melt in order of decreasing temperature or increasing frequency.

dynamic mechanical measurement A technique in which either the modulus or the damping of a material under oscillatory load or displacement is measured as a function of temperature, frequency, time, or other combinations. See **damping index; hysteresis measurement; nonresonant forced and vibration technique; relaxation; resonant force vibration; rigidity, relative; torsional pendulum.**

dynamic modulus See **modulus, dynamic.**

dynamic order of system The order of linear differential equation that describes the dynamic behavior of a system.

dynamic stress A stress that comes from a shock at a rather high speed.

dynamic viscosity See **rheological mechanical spectrometer; viscosity, absolute.**

dynamic vulcanization See **vulcanization, dynamic.**

dynamite See **powder, black.**

dynamite molding See **injection-molding nonplastic.**

dynamometer, micro- See **test, microdynamometer.**

dyne A unit of force that will accelerate a particle having a mass of 1 g/cm/s.

E

eagle wing See **rain erosion.**
earth, diatomaceous See **diatomaceous earth.**
earth protection See **geomembrane.**
earthquake See **infrastructure.**
E-beam See **sterilization, electron-beam.**
ebonite A hard moldable material made by sulfur vulcanization of rubber. Its hardness is substantially obtained by the action of sulfur. See **rubber processing; vulcanization.**
eccentricity See **mathematical dimensional eccentricity.**
ecology The study of the interactions between plant and animal organisms and their environment. The latter is conceived to include everything that is not an intrinsic part of the organism and thus includes both living and nonliving components. See **waste.**
ecology and plastic See **plastic and water conservation.**
economic See **cost; design and cost, technical cost modeling; plastic consumption; plastic economy.**
economical control of equipment Because costs rise continuously, the main consideration in investing capital must be the ratio of earnings to cost. Production aids can make a considerable contribution toward reducing costs; they include all types of auxiliary equipment as well as the major processing machines (extruder, injection-molding machine, etc.). New equipment can reduce cost of operation. Evaluating how much energy equipment requires for operation can reduce costs. See **cost reduction.**
economic and product quality A correlation exists between a company's profit margin and the quality of the fabricated products it offers, based on the fulfillment of explicit customer requirements or implicit customer expectations. The return on investment as a yardstick for a company's profit depends not only on market share but also above all on product quality. Thus, quality first provides the logical consequence of profit. See **quality.**
economic and recycling See **recycling method, economic evaluation of.**
economic cost analysis See **cost-minimization analysis.**
economic efficiency and profitability Investment decisions in private enterprise rest on the profitability of the planned actions, which is determined during the planning stage of a capital investment. The concepts of economic efficiency and profitability are in essence synonymous. In detailed profitability studies, attention should be paid to optimistic and pessimistic quantity frameworks. With such risk analysis, sales-forecast probability can be better predicted. See **business bookkeeping; capital equipment investment; cost; production capacity overhead rate; profitability study; profit plan; project checklist; risk, acceptable.**

Discounted cash flow is one of the best ways to perform economic evaluations because it expresses a project's attractiveness as an equivalent interest rate and permits direct comparison to the cost of money. Discounted cash flow also recognizes the time value of money. See **business.**

The mathematics of discounting is rigorous. Because all the cash flows in the analysis are projections, they therefore are uncertain. The plant might cost more, take longer to build, and cost more to operate than expected. Operating problems or slower sales growth might delay reaching design capacity. Selling price might fall faster than expected. Recessions might cause less than expected capacity utilization during a number of years. Reliable economic evaluations require realistic projections of these cash flows.

economic growth See **gross domestic product.**
economic indicator A measure that expresses the direction of the business economy.
economic order quantity (EOQ) The quantity that is to be produced or purchased with the lowest combined ordering and carrying cost. See **manufactured cost.**
edge bead See **extruded neck-in and beading.**
edge bowing See **packaging, edge-bowing.**
edgewise load See **loading edgewise.**
education See **quality; training; website.**
education, cost-effective See **cost-effective training.**
effectiveness, cost See **cost effectiveness.**
efficiency See **energy efficiency.**
efficient operation See **productivity.**
effluent See **waste, effluent.**
effusion See **gas effusion.**
E-glass See **fiberglass type.**
Egyptian development See **casting, investment.**
eight-harness satin weave See **fabric, woven eight-harness satin.**
EI theory See **design, EI theory.**
ejector See **mold ejector.**
Ektar Performance Plastic's trade name for its family of copolyester thermoplastic elastomer.
elastic constant See **modulus of elasticity.**
elastic deformation See **deformation, elastic; energy, plastic work; rheology.**
elastic fracture See **melt fracture.**
elastic hysteresis See **hysteresis, elastic.**
elasticity A property that causes plastic to return to its original size and shape after removal of a force causing deformation. See **coefficient of elasticity; deformation and toughness; extruder-web stretching and**

tearing; liquid, elastic; melt; processing fundamental; strain and elasticity; thermoelastic effect; viscoelasticity.

elasticity, an- The dependence of elastic strain on both stress and time. This can result in a lag of strain behind stress. In materials subjected to cyclic stress, such as fatigue, the anelastic effect causes internal damping. See **strain; stress.**

elasticity coefficient See **coefficient of elasticity.**

elasticity, high The property that a material presents when it (1) allows elastic elongation (conventionally at 100% of initial length), (2) allows the repetition of these elongations, and (3) has a short relaxation time with a low hysteresis. See **hysteresis; relaxation time.**

elasticity, melt See **melt elasticity.**

elasticity, photo See **photoelasticity.**

elasticity, theory of See **design theory and strength of material.**

elasticity, thermo- See **thermoelasticity.**

elasticity, viscous A degree of elasticity in which the time necessary to recover initial dimensions is longer than a stated time.

elastic limit See **extruder-web stretching and tearing; stress, elastic limit.**

elastic liquid See **liquid, elastic.**

elastic melt extruder See **extruder, elastic melt.**

elastic memory The ability of a thermoplastic to return to its original shape when exposed to heat beyond its heat distortion point. See **plastic memory; orientation; test, heat distortion point; thermoforming.**

elastic modulus See **modulus of elasticity.**

elasticoviscous See **viscoelastic fluid.**

elastic-plastic transition The change from recoverable elastic behavior to nonrecoverable plastic strain that occurs on stressing a material beyond its yield point. See **yield point.**

elastic recovery The fraction of a given deformation that behaves elastically. Thus elastic recovery is elastic extension/total extension. A perfectly elastic material has an elastic recovery of one. A perfectly plastic material has an elastic recovery of zero. These dimensions are expressed as percent recovery for a given percent elongation. See **recovery.**

elastic reservoir molding See **foamed reservoir molding.**

elastic response See **rheological mechanical spectrometer.**

elastic solid A material that can exist in a unique equilibrium shape at zero stress and that in which, when held in any other shape by stressing, a nonisotropic equilibrium shape exists. If both these conditions are attained instantaneously on changing the stress, then the material is perfect (or ideally) elastic. If either of these conditions takes a finite time to be attained, then the material is nonideally elastic or viscoelastic. In contrast, a liquid can have any equilibrium shape.

elastic stability The nonbuckling of parts due to compressive load. See **test, compression-property.**

elastic strain See **strain.**

elastic stress See **stress.**

elastic stress analysis See **test, nondestructive photoelastic stress-analysis.**

elastic-thermal behavior See **thermoelastic effect.**

elastic turbulence See **melt fracture.**

elastodynamic extruder See **extruder, elastic melt.**

elastomer A rubberlike material (natural or synthetic) that at room temperature stretches under low stress to at least twice its length and snaps back to approximately its original length on release of the stress (pull) within a specified time period. The term *elastomer* is often used interchangeably with the term *rubber.* Although rubber originally meant a thermoset elastomeric material obtained from a rubber tree, it identifies a thermoset elastomer or thermoplastic elastomer material. They can be differentiated on the basis of how long a deformed material requires to return to its approximately original size after the deforming force is removed and by its extent of recovery. Different properties also identify the elastomers, such as strength and stiffness, abrasion resistance, solvent resistance, shock and vibration control, electrical and thermal insulation, waterproofing, tear resistance, and cost. See **design energy and motion control; factice; latex; packing; perfluoromethylvinyl ether elastomer; rubber, natural; shock pulse; thermoplastic elastomer; thermoplastic vulcanizate; vulcanizate; vulcanized elastomer.**

elastomer adhesive, non-tacky See **fastener, nonmechanical.**

elastomer blank See **blank.**

elastomer, chlorinated See **alloprene plastic.**

elastomer, copolyester See **copolyester elastomer.**

elastomer dynamic See **damping; design energy and motion control.**

elastomer heat effect See **heat, Gough-Joule effect; test, heat Wiegand pendulum.**

elastomeric alloy A mixture that uses two or more polymers. For example, a thermoplastic vulcanizate is a fine dispersion of highly vulcanized rubber in a continuous phase of a polyolefin. Its cross-linking gives them high tensile strength, high elongation, resistance to compression and tension set, oil resistance, resistance to flex fatigue, and maximum service temperature of 135°C (275°F). See **alloy/blend; polypropylene, multiple monomer; thermoplastic elastomer; vulcanized elastomer.**

elastomeric mold A tooling system that uses the thermal expansion and particularly the flexibility of elastomers to form a mold. Some molds have a complicated cavity that flexes to remove a complex part. See **mold, elastomeric; molding, thermal expansion; reinforced plastic mold, elastomeric.**

elastomeric mold system See **molding; molding, thermal expansion.**

elastomeric shape factor For an elastomeric slab loaded in compression, the ratio of the loaded area to the force-free area. See **design shape.**
elastomer latex See **colloidal; latex.**
elastomer processing A fabricating process (such as extrusion, injection molding, blow molding, compression molding, casting, and encapsulation) that is used to process elastomers.
elastomer proof resilience The tensile energy capacity of work that is required to stretch an elastomer from zero elongation to the breaking point. See **resilience.**
elastomer reactive system See **polymer, reactive elastomer.**
elastomer, roll milling See **mill, roll.**
elastomer softener See **peptizer.**
elastomer softening See **stress softening.**
elastomer solvent curing See **adhesive contact cement.**
elastomer stretched See **heat effect, Gough-Joule.**
elastomer stretched adiabatically See **heat effect, Gough-Joule.**
elastomer temperature effect See **temperature flexibility, plastic.**
elastomer, vulcanized See **factice; vulcanized elastomer.**
elastoplastic A substance that exhibits a greater or lesser degree of resiliency and returns to its original size and shape if deformed to some extent below its elastic limit. See **resilience.**
electrical alternating current (AC) An electric current that reverses its direction at regularly recurring intervals. Opposite of direct current (DC).
electrical ampere The constant current that, if maintained in two straight parallel conductors of infinite length of negligible circular cross-section and placed one meter apart in a vacuum, would produce between these conductors a force equal to 2×10^7 Newton per meter of length.
electrical and orientation property See **orientation and electrical property.**
electrical anode The positive electrode of an electrolytic cell to which negatively charged ions travel when an electric current is passed through the cell; the electrode that supplies electrons to an external circuit.
electrical antistatic plastic See **antistatic agent.**
electrical arc resistance The total time in seconds that an intermittent arc may play across a plastic surface without rendering the surface conductive because of carbonization by the arc flame.
electrical arc tracking A phenomenon that occurs on the surface of an insulator when an arc is set up near that surface, under a low voltage, such as 10 to 20 amperes.
electrical breakdown voltage The voltage required, under specific conditions, to cause the failure of insulating material.
electrical cable armor A solid or braided metal jacket for imparting maximum abrasion resistance to the complete cable. Braided armor is sometimes used in lieu of solid armor for improved flexibility. See **extruder wire and cable.**
electrical cable "button" Coaxial electrical cables use different plastic-fabricating solid and foam techniques for insulation between the outer conductor and the central wire conductor. Polystyrene plastic insulation disks (buttons) can be injection molded using a cold or hot runner system with accurate dimensions of the buttons and their spacing along the central wire. Multiple copper center wire conductors (10 or more) can be continually moving from their manufacturing process through the mold halves. Multiple cavities (10 or more) are located inline with each wire. The injection molding machine (IMM) is located on a rectangular moving platform to automatically close on the guided wires. It moves forward at the rate of the wire movement during which time the buttons form and solidify around the wires. The mold opens and moves sideways away from the direction the injection-molding machine moving platen moves (removing buttons from the mold multiple cavities) and returns to its starting position to accurately locate and inject another series of buttons. See **injection molding; polystyrene plastic.**
electrical capacitance A system of conductors and dielectrics that permits the storage of electricity when potential difference exists between the conductors. Its value is expressed as the ratio of a quantity of electricity to a potential difference with its value always being positive. See **dielectric; electrical cure monitoring; permittivity, relative.**
electrical charge See **piezoelectric effect.**
electrical circuit See **injection-molding circuit board; integrated circuit; printed circuit board.**
electrical coercive field Electric field required to remove residual polarization.
electrical coil impregnation See **impregnation, trickle.**
electrical conductance The siemens (S) is the electric conductance of a conductor in which a current of one ampere is produced by an electrical potential difference of one volt (A/V). See **electrical surface conductance.**
electrical conductivity A conductive thermoplastic may inherently be electrically conductive but usually has been modified with electrical conductive additives. The plastics used include principally ABS, HDPE, LCP, LDPE, PA, PBT, PC, PEEK, PEI, PES, PET, PK, PMMA, POM, PP, PPA, PPO, PPS, PS, PSO, PUR, PVDF, SPS, TEO, TES, and TPE. Various additives are used, such as coatings, antistatic agents, metal powders or plates, carbon fibers, metal-coated glass fibers, and stainless steel fibers. In addition to these more conventional additives, more recently different metal-coated substrates, intrinsically conductive polymers (ICPs), and intrinsically dissipative polymers (IDPs) provide a wide range of conductive plastics. Varying the percentage or type of conductivity additive used in a compound permits controlling the degree

of electrical resistivity. Most of these conductive plastics can be made in a variety of colors. With a precolored conductive thermoplastic, the color is in the material rather than added as a secondary operation. See **antistatic agent; carbon black, conductive; chrome plating; fiber, carbon; electromagnetic interference; insulation resistance; iron; packaging, electronic; plastic electrically conductive; test, conductivity. Appendix A, List of Abbreviations.**

electrical conductor A wire or combination of wires not insulated from each other, suitable for carrying electricity. Some plastics are electrical transparent conductors. See **carbon black; element, semiconductor; piezoelectric plastic.**

electrical connector A device to join two or more electrical conductors. Connectors perform simple and vital roles. Their design is constantly changing as the technology around them change. In the beginning of the twentieth century, thermoset plastics were the dominant materials of construction. By the 1960s thermoplastic materials took over the connector market. Performance requirements include precision control of miniature multiple connectors with injection molding being the major production method used. See **fastener; orientation and heat-shrinkability.**

electrical corona An electrical discharge effect that causes ionization of oxygen and the formation of ozone. It is particularly evident near high-tension wires and in spark-ignited automotive engines. The ozone formed can have a drastic oxidizing effect on certain plastic wire insulation, cable covers, and hose connections unless oxidation-resistance nylon, neoprene, and other plastics are used. See **antioxidant agent; electrical erosion breakdown; ozone.**

electrical corona discharge treatment The flow of electrical energy from a conductor to the surrounding air or gas causes an electric discharge to ionize the surrounding gas, usually air. The treatment is a plastic surface preparation that is used in adhesive bonding and films. Treating inert plastics such as polyolefins increases its affinity to inks, adhesives, and coatings. For example, application in a film line has the film passing over a grounded metal cylinder with a pointed high voltage electrode above it to produce a discharge. The phenomenon occurs when the voltage is high enough (5000 or more volts) to cause partial ionization of the surrounding gas. The discharge is characterized by a pale violet glow, a hissing noise, and the odor of ozone. This treated gas reacts with the plastic, roughening the surface to provide sites for mechanically interlocking and introducing reactive sites on the surface. The treatment takes place only on the exposed surface to a depth of only 10 angstrom. Proper handling of the web is required to eliminate problems such as air entrapment and wrinkles on the backside. Also called *corona treatment.* See **decorating preparation problem; film decorating; surface treatment; plasma treatment.**

electrical corona, prevent backside treatment Backside treatment is an undesirable consequence of corona treating of plastic films. Corona equipment forms an electrical capacitor, consisting of a top plate where an electrode is connected to a high-voltage source and a bottom plate that is the core of the ground roll connected to the ground. The bottom plate is separated from the top plate by several dielectrics, an air gap, the film to be treated, and the roll covering (usually rubber, silicone, epoxy, glass, quartz, or ceramic). As the voltage increases on the top plate, the air in the gap ionizes, forming a purple glow called *corona.* As the corona meets the surface of the film being treated, it causes the surface to oxidize, forming oxygen radicals that attach to the film's polymer chains. The oxygen radicals are receptor sites for the adhesion of coatings such as inks, adhesives, molten polymers, and liquid coatings. Corona treatment occurs only on the film's surface.

Undesirable backside treatment occurs if air becomes trapped between the film and rolls. Several conditions can lead to this air entrapment, including wrinkles in the film web as it passes over the treater roll, low web tension, and a web moving so fast that the film is lifted off the treater roll. Foreign materials on the roll, such as dirt, oxidation, resin dust, and slip buildup, can also result in trapped air. Backside treatment can cause problems in the rewind stage; the film can block, and the roll will be difficult or impossible to unwind. Correcting the problem depends on its cause. Sometimes all that is needed is cleaning, and a maintenance program should be instituted. If oxidation is the problem, it might be necessary to replace the treating roll with one having a higher resistance to oxidation. Rolls range from low-cost aluminum that is easily oxidized to more expensive titanium that is free of oxidation.

electrical corona resistance The resistance to an ionizing process. When an electric current passes through a conductor, it induces a surrounding electrostatic field. If voids exist in the insulation near the conductor, the high-voltage electrostatic field may ionize and rapidly accelerate some of the air molecules in the voids. These ions can then collide with the other molecules and ionize them, thereby developing a hole in the insulation. See **ionization.**

electrical corona shield An electromagnetic interference-type of plastic or metal that is placed around exposed high-voltage components to prevent electrical discharge or transmission. See **electromagnetic interference.**

electrical coulomb (C) The quantity of electricity transported in one second by a current of one ampere (A).

electrical coulometer An electrolytic cell arranged to measure the quantity of electricity by the chemical reaction produced in accordance with Faraday's law.

electrical covering In wire coating, a coating whose primary purpose is to weatherproof, to prevent casual grounding (such as contact with a wet tree), or to otherwise protect a conductor. See **extruder wire and cable.**

electrical creepage The electrical leakage on a solid dielectric surface.

electrical cure monitoring The use of electrical techniques to detect changes in the electrical properties or mobility of the plastic molecules during cure. An example is measuring thermoset plastic cure. See **cure; thermoset plastic curing, dielectric monitoring.**

electrical current See **measurement.**

electrical current density See **electroplating current density.**

electrical dielectric See **dielectric.**

electrical, direct current (DC) An electrical current flowing in one direction only and substantially constant in value. When electrical voltage is applied to a material, current flows. Voltage is never absolutely steady and usually varies in an alternating current (AC) cyclic fashion. The DC resistance depends on the dimensions of the material and a number of factors such as ambient conditions, heat induced by the current flow, and the characteristics of the material.

electrical-discharge machine (EDM) A method of manufacturing tools (molds, dies, cutters, etc.) by using controlled sparking to erode or remove the metal work pieces.

electrical dissipation factor The ratio of the power loss in a dielectric material to the total power transmitted through it. It is equal to the tangent of the loss angle or to the ratio of the dielectric loss to the dielectric constant. See **orientation and electrical property.**

electrical dry cell A primary battery that has a zinc anode, a carbon or graphite cathode surrounded by manganese dioxide, and a paste containing ammonium chloride as the electrolyte and that can be encased in plastic.

electrical eddy current A current that is caused to flow in a conductor by the time or space variation, or both, of an applied magnetic field.

electrical eddy current, standard depth of penetration in the The depth at which the eddy-current density is reduced to about 37% of the density at the surface. Eddy-current testing is most effective when the wall thickness does not exceed the standard depth of penetration (SDP) or in heavier tube walls when discontinuities of interest are within one SDP. See **test, nondestructive electrical eddy-current.**

electrical eddy-current testing See **test, nondestructive electrical eddy-current.**

electrical-electronic market The fifth-largest market for plastics. Many new and important developments in the field of electricity and electronics would not have been possible without the many and continuing developments in the field of plastics. Their wide use is based primarily on their excellence as insulating materials with toughness. Although insulation requirements vary widely, one or more plastics will meet literally every requirement. See **market.**

electrical energy See **chemistry, electro-.**

electrical erosion breakdown In an electrical conductor insulation, a breakdown that is caused by a chemical attack by corrosive chemicals, such as ozone and nitric acid, that are formed by corona discharge from a high-voltage cable. See **electrical corona; erosion.**

electrical fire hazard See **fire retardance; flammability.**

electrical galvanic cell A cell containing two dissimilar metals and an electrolyte.

electrical hall effect When current is passed through a semiconductor bar situated within a magnetic field that is perpendicular to the direction of current and a voltage is developed across the bar.

electrical inductance The henry (H) is the inductance of a closed circuit in which an electromotive force of one volt is produced when the electric current in the circuit varies uniformly at a rate of one ampere per second.

electrical insulation, askarel A group of nonflammable chlorinated hydrocarbons that are used as electrical insulating media. Various composition types are used. Under arcing conditions the gases produced, while consisting predominantly of noncombustible hydrogen chloride, can include varying amounts of combustible gases depending upon the askarel used. See **hydrogen chloride.**

electrical insulation, rigid Those materials having a minimum flexural modulus of 10^5 psi (7000 kgf/cm^2) as determined by ASTM method D-790, Test for Flexural Properties of Plastics.

electrical insulation fish paper See **vulcanized fiber fish paper.**

electrical interference See **electromagnetic interference.**

electrical jacket A tough sheath that protects an insulated wire or cable or permanently groups two or more insulated wires or cables.

electrical law, Faraday See **electricity, Faraday's law of.**

electrical-loss angle The antitangent of the electrical dissipation factor. See **dielectric-loss angle.**

electrical-loss angle, tangent The dissipation factor of an electrical condenser of which the insulating material forms the dielectric when the electrodes of such a condenser are subjected to an alternating emf (electromagnetic frequency). Also called *damping factor.* See **damping; dielectric-loss factor.**

electrical-loss factor The product of the power factor and the dielectric constant.

electrically conductive plastic See **plastic conductivity; plastic, electrically conductive.**

electrical-mechanical motion See **piezoelectric plastic.**

electrical moisture content test See **moisture content; test, reinforced-plastic moisture content.**

electrical motion control system See **design, motion-control, mechanical and electronic effects; motion-control system; potentiometer.**

electrical operating injection-molding machine See **injection-molding machine electrical operation.**

electrical orientation See **orientation and electrical property.**

electrical ozone See **antioxidant agent; electrical corona; ozone.**

electrical peak voltage For AC meters, the voltage that will discharge across the air gap or across a defect. The peak voltage is the root mean square (RMS) voltage multiplied by 1.414. See **electrical volt.**

electrical permeability, magnetic The ratio of induction to magnetic field.

electrical permittivity A factor that gives the influence of an extensive, isotropic dielectric medium on the forces of attraction or repulsion between two electrified bodies. It is the product of the relative permittivity and the permittivity of free space (vacuum). See **permittivity, relative.**

electrical piezoelectric effect See **piezoelectric effect.**

electrical power The watt (W) is the power that gives rise to the population of energy at the rate of one joule per second (J/s). See **electrical watt.**

electrical power device See **electronic standard, international.**

electrical power disturbance A power disturbance that is caused by electromagnetic interference, radio-frequency interference, and electrostatic discharge. These three interference situations can cause functional upsets and damage to electronic components. In some cases, such as medical devices, life-threatening device malfunctions can occur. See **safety.**

electrical power factor The ratio of total power loss (watts) to the product of voltage and current in an electrical condenser in which the insulating material forms the dielectric. It is the cosine of the angle between voltage applied and the resulting current. Measurements are usually made at million-cycle frequency.

electrical power loss The power, per unit volume, that is transformed into heat through hysteresis. It is the product of energy loss and frequency.

electrical printed circuit board See **printed circuit board.**

electrical property Many plastics are electrical insulators or dielectrics and exhibit high resistivity (low conductance). Electrical behavior of plastics is influenced by factors such as temperature, time in service, moisture and other contaminants, geometric relationships, mechanical stresses, and frequency with magnitude of the applied voltage. These factors interact in a complex fashion. See **dope; mechanical property; orientation and electrical property; periodic table; physical property; test, chemical property; zirconium oxide.**

electrical quantity See **electrical coulomb.**

electrical radiation Energy that is in the form of electromagnetic waves; the emission of such energy. It often is found in connection with radio frequency (RF) preheating. See **radio-frequency preheating.**

electrical resistance See **electrical wheatstone bridge; insulation resistance.**

electrical resistance strain gauge See **strain gauge.**

electrical resistance temperature detector See **temperature electrical resistance detector.**

electrical resistivity The ability of a material to resist passage of an electrical current either through its bulk or on its surface.

electrical root-mean-square (RMS) voltage Root-mean-square voltage, or average voltage, that is shown on an alternating-current test meter.

electrical schematic A diagram of a detailed arrangement of circuits and hardware using applicable electrical and engineering symbols.

electrical SCR drive A silicon-controlled rectifier (SCR) motor drive system that controls the speed of a direct-current motor by the use of rectified pulses of electrical power. This means that an alternating-current supply is converted to appropriately sized DC pulses as indicated by a speed-measuring device. See **electric motor.**

electrical semiconductor See **semiconductor.**

electrical shielding See **carbon black, conductive.**

electrical spark-over A disruptive discharge between electrodes of a measuring gap, such as a sphere or oil testing gap.

electrical-spark test, coating See **test, electrical-spark coating.**

electrical-spark tracking A phenomenon that occurs on the surface of an insulator when, between two metallic parts, the voltage rises to a value high enough to produce a spark.

electrical static charge See **electrostatic charge.**

electrical-strain gauge See **strain gauge.**

electrical strength See **dielectric strength.**

electrical-surface conductance The direct current conductance between two electrodes in contact with a specimen of solid insulating material when the current is passing only through a thin film of moisture on the surface of the specimen. See **electrical conductance.**

electrical-surface leakage The passage of current over the boundary surfaces of an insulator as distinguished from passage through its volume.

electrical-surface resistance The ratio of the direct voltage applied to the electrodes to that portion of the current between them that is in a thin layer of moisture or other semiconducting material that may be deposited on the surface.

electrical-surface resistivity The ratio of the potential gradient parallel to the current along its surface to the current per unit width of surface. It is numerically equal to the surface resistance between two opposite sides of a square of any size when the current flow is uniform. See **test, conductivity.**

electrical switch A switch that takes advantage of plastics properties and processing techniques. For example, a folded-membrane switch uses thin flexible film with associated electrical connections.

electrical system, corrosive See **phosphorous-base flame retardant.**

electrical testing See **test, nondestructive electrical; test, nondestructive electrical eddy current.**

electrical tracking A phenomenon wherein a high-voltage source current creates a leakage or fault path across the surface of an insulating material by slowly but steadily forming a carbonized path.

electrical track resistance See **electrical-arc resistance.**

electrical transparent conductor A transparent conductive film for electronic components. Their uses include electroluminescent lamps, membrane-touch panels, electromagnetic interference and radio-frequency interference shielding, plastic liquid crystal displays, ground-planes, heating elements, solar control window films, laser printers, transparent packaging barrier coatings, photoreceptor ground-planes, and anticounterfeiting pigment for high-value currency and documents.

electrical volt (V) The difference in electric potential between two points of a conductor carrying a constant current of one ampere (A) when the power dissipated between these points is equal to one watt (W/A). See **redox potential.**

electrical-voltage deviation, root-mean-square See **deviation, root-mean-square voltage.**

electrical-volume resistivity The ratio of the electrical potential gradient to the current density when the gradient is parallel to the current in the material. Also called *specific insulation resistance.* See **test, conductivity.**

electrical watt A unit of active power. One watt is energy, work, or quantity of heat expended at a rate of one joule per second. See **electrical power.**

electrical-watt density The watts per unit area emitted from radiant heaters.

electrical wheatstone bridge A divided electrical circuit used for the measurement of resistance. An example is a network of four resistors, an emf source, and a galvanometer connected such that the galvanometer will show a 0 or null reading when the resistance is matched. See **insulation resistance.**

electrical wire resistant strain gauge See **strain gauge; stress-strain curve.**

electric charge See **antiparticle.**

electric hygrometer See **hygrometer.**

electricity The word *electricity*, coined in the eighteenth century, was derived from the Greek word for amber (*elektron*).

electricity, Faraday's law of The quality of electricity that can deposit, or dissolve, one gram-equivalent weight of a substance during electrolysis (about 96.500 coulombs).

electricity, static See **electrostatic charge.**

electric motor Practically all basic and auxiliary processing equipment uses electric-drive motors. The direct-current motors are the most popular. They can be controlled through solid-state circuitry that rectifies the alternating-current supply. Apart from being one of the most efficient motors in the speed range of 20% to 100% of maximum, DC motors give a wide range of controllable speeds of better than 30:1. A major disadvantage is the tendency of the speed to drift as the motor warms up, though this can be reduced by feedback speed controls. The variable-speed AC-drive motors are popular. Main-frequency supply is rectified to DC and then converted to a variable-frequency wave front using solid-state switching devices. Their nonsinusoidal waveform can cause power loss; using more silicon-controlled rectifiers (SCRs) can reduce it. However, this action increases the cost of the normally lower-cost motor when compared to the DC types. Two major advantages of the variable-frequency AC-drive motor are the better power factor and lower maintenance. See **design, motion-control, mechanical and electronic effects; drive-system control; electric motor drive; electrical SCR drive; energy loss, machine; extruder drive-energy consumption; extruder specification drive; injection-molding machine-drive system; injection-molding machine electrical operation; motion-control system; thyristor.**

electric motor, adjustable-speed-drive (ASD) An ASD (adjustable-speed-drive) can cut energy use, improve process efficiency, and minimize machine wear and tear. Energy savings and efficiency stem from the ASD's precise electronic control of motor speed. They provide "soft" starts extending the life of the components they drive such as hydraulic pumps, fans, and seals on rotating shafts. See **accuracy; control drive, optimized; energy loss, machine; extruder drive-energy consumption; injection-molding machine, electrical operation; motion-control system; repeatability.**

electric-motor air-flow switch A switch fitted on the exit side of the cooling circuit of an electric motor that prevents motor overheating if the airflow fails. It is particularly useful in a material powder environment.

electric-motor drive A silicon-controlled rectifier is a motor-drive speed-control system that controls the speed of a direct current motor by use of rectified pulses of power. See **electric motor; repeatability; servo-control-drive reliability.**

electric-motor motion See **motion-control system.**

electric-motor stalling/slippage See **extruder-web tension control, slipping and tearing.**

electric-panel heater See **thermoforming heater, electric panel.**

electric-power motion See **motion-control system.**

electric-system corrosiveness See **phosphorus-base flame retardant.**

electrification time The time during which a steady direct potential is applied to electrical insulating materials before the current is measured.

electrochemical cell A system consisting of an anode and a cathode in metallic contact and immersed in an electrolyte.

electrochemical reaction Many chemical reactions can be classified as oxidation-reduction reactions, or *redox reactions*, and can be considered to be the result of two reactions with one oxidation and the other reduction. See **redox plastic.**

electrochemistry See **chemistry, electro-.**

electrocoating See **electroplating.**

electrode **1.** The energized or grounded conductor portion of electrical test equipment, which is placed near or in contact with the material or equipment being tested. **2.** A terminal point in an electric circuit that is designed to promote an electric field between one electrode and another. It is used in radio-frequency heating, surface treatment of polyethylene film, and so on. See **corrosion, passivation.**

electrodeposition coating See **coating, electrodeposition.**

electro discharge machine (EDM) A machining process that uses a carbon electrode that is shaped to the same geometry as is required in the final molded part. The electrode is held in a close proximity to the material while in solution. An electrical current is passed through the electrode, locally eroding the base material away until the desired shape is achieved. See **machining.**

electroerosive cutting and sinking Electrical arc and chemical techniques used in metal cutting. Processes for manufacturing plastic processing mold and die tools as well as cutting and stamping tools. See **film perforating; machining; mold-cavity hobbing.**

electroforming The production or reproduction of a product by electrodeposition on a mandrel or mold that is subsequently separated from the pattern. This mold cavity form can be supported or strengthened by using a backup material such as reinforced plastic or foam compound or by spraying low-melt metal alloys. The pattern material can be wax or a flexible material. The molded part usually employs a low or moderate pressure. See **mold material; thermoforming.**

electroless plating The deposition and formation of a continuous metallic film on a nonconductive plastic surface without the use of an electric current. Plating materials include copper, nickel, chromium, and silver. The process involves the controlled reduction of a solution of a metal ion by a dissolved reducing agent at a catalytic interface to give a coherent film. The plating depends on a precise series of chemicals to clean, roughen, and catalyze the surface before plating. See **plating; surface finish.**

electroluminescence Luminescence that results from electrical excitation. See **luminance.**

electrolysis A method by which chemical reactions are carried out by an electric current that passes through a solution of an electrolyte or through a molten salt. See **decomposition; chemical reaction, half-cell.**

electrolyte A substance that provides ionic conductivity when dissolved in water or when in contact with it. Such compounds may be either solid or liquid types including acids, bases, and salts, or other media such as ionized gases. See **electroplating; molecular conductivity; nonelectrolyte.**

electrolytic, conductimetry See **conductimetry.**

electromagnet A soft iron core that is surrounded by a coil of wire that temporarily becomes a magnet when electric current flows through the wire. See **magnet.**

electromagnetic adhesive See **adhesive, electromagnetic.**

electromagnetic compatibility (EMC) Designing devices to minimize the risks that are associated with reasonably foreseeable environmental conditions. They include magnetic fields, external electrical influences, electrostatic discharge, pressure, temperature, or variations in pressure and acceleration, and reciprocal interference with other devices normally used in investigations or treatment.

electromagnetic curing See **thermoset plastic curing, electromagnetic.**

electromagnetic field (EMF) The magnetic force that is developed by the passage of an electric current through a conductor core usually wrapped around an iron or similar metal or alloy. See **fiber optic; holography; infrared spectroscopy; neutron scattering.**

electromagnetic-induction welding See **welding, electromagnetic-induction.**

electromagnetic interference (EMI) The interference related to accumulated electrostatic charge in a nonconductor. As electronic products become smaller and more powerful, there is a growing need for higher shielding levels to ensure their performance and guard against failure. In the past the 40 dB shielding was the norm, but the 60 dB is becoming the normal higher value. The plastic shielding material used may include the use of additives. Designs may include board-level shielding of circuit, bondable gaskets, and locating all electrical circuits in one location so only that section requires appropriate shielding. Designers of enclosures for electronic devices should be aware of changes in electromagnetic compatibility (EMC) that tend to continually develop worldwide. Conductive plastics provide electromagnetic interference and radio-frequency interference shielding by absorbing electromagnetic energy and converting it into electrical or thermal energy. They also function by reflecting EME. This action ensures operational integrity and electromagnetic compliance with existing standards. Conductive plastics are generally designed to meet specific performance requirements (physical, mechanical, etc.) in addition to EMI/RFI or static control. Often these plastics have to perform structural functions, meet flammability or temperature standards, provide wear or corrosive resistant surface, and so on. Also called *radio-frequency interference (RFI)* and *static charge*. See **antistatic agent; electrical conductivity; electrical corona shield; electronic standard, international; heating, dielectric; light scattering; metal-to-plastic bond; molecule, polar; packaging, electronic; piezoelectric plastic; plastic conductivity; plastic dopant; plastic, electrically conductive; safety; semiconductor; static; test, conductivity; thermal conductivity.**

electromagnetic interference, shielding-effective-

ness (SE) of SE is the ratio of the incident field strength to the transmitted field strength. Frequency range is from 30 MHz to 1.5 GHz (ASTM D 4935-89). See **test, conductivity.**
electromagnetic phenomena See **heating, dielectric.**
electromagnetic radiation See **cross-linking, radiation; infrared spectroscopy.**
electromagnetic radiation quanta energy The smallest quantity of energy that can be emitted or absorbed in the form of electromagnetic radiation. See **spectrum.**
electromagnetic spectrum The wavelength regions from 10^{-14} to 10^{4} m that go from x-ray, ultraviolet, visible near infrared, mid-IR, far IR, microwave, to radio. They are energy propagated by an electromagnetic field. See **heating, microwave; light; light scattering; sensor, infrared.**
electromagnetic testing See **test, nondestructive electromagnetic.**
electromagnetic welding See **welding, electromagnetic-induction.**
electromotive force (EMF) The maximum potential difference between two electrodes in a given cell.
electron A fundamental particle of matter that can exist either as a constituent of an atom or in a free state. It has a negative charge. The number of electrons in an atom of any element is the same as the number of protons in the nucleus and the atomic number. Electrons can be removed from the atoms of metals and some other elements by means of heat, light, electric energy, and bombardment with high-energy particles, such as radiation and ionization. See **electron, Lewis acid; periodic table; radioactive beta particle.**
electron acceptor See **acceptor.**
electron affinity The energy that is released when an electron is added to an atom in the gaseous state.
electron beam A stream of electrons in an electron optical system. See **sterilization, electron-beam.**
electron-beam polymerization See **polymerization, electron-beam.**
electron beam radiation The ionizing radiation that is propagated by electrons that move forward in a narrow stream with about equal velocity. See **radiation.**
electron beam treatment (EB) A modification of large-volume thermoplastics and reinforced plastics. It has been used as an alternative to chemical treatment of plastics in or after processing and to control plastic rheology. Examples include modifying PP melt strength, flow behavior, and molecular structure in complex ways. PE melt indices are reduced. PVC impact strength is increased via EB cross-linking. EB accelerators generate a curtain of ionizing radiation. If dosed to excite the right electrons to the right degree, EB can precisely change part or all the plastic structures and eliminate thermal degradation and residues associated with chemical processes. See **cross-linking; printing ink, radiation.**
electron-beam welding See **welding, electron-beam.**
electron-bond order The difference between numbers of electrons in bonding molecular orbitals and antibonding molecular orbitals, divided by two.
electron bond, sigma The bond that is formed when two electrons are placed in a sigma-bonding molecular orbital.
electron configuration The distribution of the electrons in an atom among the atomic orbitals.
electron-deficient compound A compound in which the number of valence electrons available around an atom, other than hydrogen, is fewer than eight.
electron density The probability that an electron will be found at a particular region in an atomic orbital.
electron diffraction The phenomenon or the technique of producing diffraction patterns through the incidence of electrons on matter.
electron diffraction band A maximum broad intensity with sharp edges.
electronegativity The ability of an atom to attract electrons toward itself in a molecule.
electron gun A device for producing and accelerating a beam of electrons.
electronic A branch of physics that deals with emission, behavior, and effects of electrons and with electronic devices. See **mechatronic.**
electronic and mechanical effect, design motion control See **design, motion-control, mechanical and electronic effects.**
electronic chip Traditional chips are encapsulated with a plastic that is almost always epoxy plastic. The glob-top microprocessing chips have only a single drop of epoxy applied to their tops. See **business card, electronic; integrated circuit, plastic.**
electronic control See **control drive, optimized; integrated circuit; nanotechnology.**
electronic data interchange (EDI) A method that is used for ordering, shipment, receiving, billing, and payment between customer and supplier. This type of exchange of data is usually through a third neutral computer company that safeguards the information. See **engineered, re-; production data acquisition.**
electronic document and retrieval system See **computer electronic document and retrieval system.**
electronic doppler effect A shift toward longer electronic wave lengths for waves reaching an observer when the source of the waves is moving away from the observer or instrument (radar device, etc.). The doppler effect is the apparent difference between the frequency at which light waves or sounds leave a source and that at which they reach the observer. The effect is caused by the relative motion of the observer and the wave source. As you approach a blowing horn, for example, the perceived pitch becomes higher until you reach the horn and then lower as you move away. See **radome.**
electronic dot generation See **printing, electronic dot generation.**
electronic heating See **heating, dielectric.**

electronic image processing See **printing, photoengraving.**
electronic logic control See **control, electronic logic.**
electronic microminiaturization The technique of packaging a microminiature part or assembly composed of elements radically different in shape and form factor. Electronic parts are replaced by active and passive elements through the use of fabricating processes such as screening, vapor deposition, and diffusion. See **casting; encapsulation; nanotechnology; packaging, electronic; printed circuit board, surface-mounted technology.**
electronic module coating See **parylene plastic.**
electronic packaging See **packaging, electronic.**
electronic printing See **printing electronically.**
electronic shielding See **carbon black, conductive.**
electronic standard, international For most of the world's important markets, the International Electrotechnical Commission (IEC) 601 series of standards for electromedical and nonmedical equipment is important. It is estimated that over half of all types of the many medical devices are electrically powered. IEC refers to a series of already issued or envisioned technical standards for ensuring the electrical safety of devices. They include both electromagnetic emissions and immunity to such emissions from other sources. Although compliance with these standards is in theory voluntary, they are rapidly becoming de facto regulatory requirements throughout much of the world. This standard and Underwriters' Laboratory 544 standard are virtually identical except for some national deviations allowed by the IEC rules. See **medical applications; safety.**
electronic toys See **plastics and electronic toys.**
electronic treatment A method of oxidizing a polyolefin part to render it printable by passing it between electrodes and subjecting it to a high-voltage corona discharge. It also provides other advantages, such as permitting adhesive bonding. See **electrical corona discharge treatment; plasma treatment; surface treatment.**
electron image A representation of an object formed by a beam of electrons focused by an electron optical system.
electron, Lewis acid A substance that can accept a pair of electrons. See **resonance.**
electron, Lewis base A substance that can donate a pair of electrons.
electron, Lewis structure A representation of covalent bonding using the Lewis symbols.
electron, Lewis symbol The symbol of an element and one or more dots representing the number of valence electrons in an atom of the element. See **valence.**
electron microscopy See **chemistry, analytical; molecular-level electron microscope; transmission electron microscope.**
electron scattering The scattering of electrons by any crystalline material through discrete angles. The angles depend only on the lattice spacing of the material and the velocity of the electrons. See **radiation, diffraction.**
electron spin resonance spectroscopy (ESR) A form of spectroscopy that is similar to nuclear magnetic resonance except that the specimen is as unpaired electron, not a magnetic nucleus. See **spectroscopy; spectroscopy, nuclear magnetic resonance.**
electrophoresis The migration of suspended or colloidal particles in a liquid such as rubber latex due to the effect of potential differences across immersed electrodes. It is one of a group of phenomena referred to generally as *electrokinetic phenomena,* which include electroosmosis and streaming potential as well as electrophoresis. The term *ionophoresis* is sometimes used for the migration of low-molecular-weight substances in an electric field, especially when the migration takes place in a stabilizing medium such as a gel. See **latex, natural rubber; latex, rubber or plastic; molecular weight.**
electrophoretic deposition The process of depositing material on a work piece by immersing in a liquid suspension of the coating plastic material. It is similar to electroplating in which the work piece forms one electrode of a pair immersed in the bath. On application of direct-current voltage to the electrodes, particles of the suspended material migrate to the work piece due to the movement of particles under the influence of the impressed DC voltage. Plastics used include PVC, PVDC, PE, and PTFE. See **plating.**
electroplating The process of applying an adherent metallic coating, such as chromium, nickel, copper, and silver, on a plastic part by passing an electric current through an aqueous solution of a salt containing ions of the element being deposited. The material being plated constitutes the cathode. Plastics are generally not conductive, so they are made conductive by different methods such as pretreating with a base conductive coating or the plastic includes conductive filler. An understanding of this electro system and the fabricating process is required. Stresses in a molded part can have immediate or in service delamination of the coating due to stress relieving or relaxation causing the plating to separate from the plastic. See **coating, sputtered; ionization; stress relaxation; metallizing plastic.**
electroplating current density The electric current per unit area or surface of the product being plated. It is expressed in amperes per cm^2 or more usually A/cm^2.
electrospray mass spectrometry (ESMS) A method of spraying a plastic solution through a fine jet to give a supersonic molecular beam. In this way it is possible to produce isolated and charged molecules that will be analyzed according to their mass.
electrostatic The science of forces and fields of electric charges in a state of rest.
electrostatic assist While electrostatic forces may cause the disintegration of a fluid stream, this method is not used alone. It is extremely useful as an assist with spray methods, especially with centrifugal spraying. An electrostatic force improves the disintegration of the electrically charged paint stream, but most important, it directs the charged paint particles to the oppositely charged target, usually at

ground potential. This increases transfer efficiency. The plastic surfaces are made conductive by a light spray of conductive salt sufficient to maintain the required charge on the part to be painted. See **spray, airless.**

electrostatic charge The electrical charge that is produced by the relative motion of a nonconducting material over a nonconducting plastic material. Charge separation is due to mechanical motion. The charge, often negative, is induced or transferred onto a surface. Static electrical charging by contact electrification (triboelectrification) is a property of interest in commercial applications. A triboelectric series may be established that roughly follows the dielectric constants of plastics. See **antistatic agent; destaticization; static charge.**

electrostatic-charged area development See **printing, electrostatic-charged area development.**

electrostatic charge on film See **film, electrostatic charge.**

electrostatic discharge detector (ESD) A detection device that provides visual identification that an ESD event has occurred on a printed circuit board or an electronic subassembly. The plastic enclosed unit is designed to be mounted to ESD-sensitive circuit boards and assemblies during their manufacture. If the ESD detector detects damage during manufacture or in shipment, a display indicates this damage.

electrostatic dissipative See **electromagnetic interference.**

electrostatic precipitator See **pollution, air.**

electrostatic spray coating See **coating, electrostatic spray.**

electrovalent bond See **atom electrovalent bonding.**

element A substance made up of atoms with the same atomic number (periodic table). The element is a pure substance, such as hydrogen, gold, and iron, that cannot be broken down by chemical means to a simpler substance. Elements are listed in the periodic table. This table lists 109 elements by atomic numbers. The element hydrogen was assigned an atomic number of 1, and all the others derived their atomic numbers from a comparison of the size of the atoms to the element hydrogen. The atomic number is actually the number of protons in the nucleus of an atom. Atoms are far more complicated, but present knowledge characterizes atoms as being composed of protons (positively charged particles), neutrons (neutral particles), and electrons, which orbit the nucleus (or core of an atom). Atoms are often characterized as a sun (nucleus) surrounded by orbiting planets (electrons). Electrons have mass, but their orbits are not well defined rings. Many intricacies are involved in analyzing the nuclear atom and in evaluating bonding tendencies between atoms. Also called *chemical element.* See **atom; carbon; compound, -ide; engineering material; periodic table; valence.**

element, definite proportion law The combination of elements in simple ratios of 1 : 1, 2 : 1, 2 : 3, 3 : 4, and so on.

element, molar mass See **molar mass of an element.**

element, semiconductor An element that normally cannot conduct electrical current but can have their conductivity greatly enhanced either by raising the temperature or by adding certain impurities. It is a strongly negative element. It is called nonmetallic and has a tendency to acquire electrons. See **conductivity; semiconductor.**

element, strongly positive A metallic element that has a tendency to give up electrons.

element, transmutation The conversion of one element into another.

element, transuranium Elements with atomic numbers greater than 92.

Ellis model See **viscosity, non-Newtonian flow Ellis model.**

Elmendorf tear test See **test, tear-resistance.**

elongation The amount of increase in length resulting from, as an example, the tension load applied. It is usually expressed as a percentage of the original length. It is also identified as the strain or stretch of a material. Also called *extensibility.* See **extensibility; deformation; fabric, elastic; strain; strain extensometer.**

elongation, creep See **creep.**

elongation, elastic See **elasticity, high.**

elongation, fatigue See **fatigue.**

elongation, hot The elongation or extensibility of a heated thermoplastic sheet. This extensibility varies widely with the material and is also greatly affected by sheet temperature, speed of stretching, and method of stretching (by differential air pressure or mechanical means). See **orientation.**

elongation, maximum The elongation at the time of failure or rupture, including both elastic and plastic deformation of the test specimen. Also called *ultimate elongation, elongation at rupture,* or *break elongation.*

elongation, melt-flow See **melt-flow elongation.**

elongation set at break The elongation measured after rupture on a test specimen. See **test set, immediate.**

elongation, uniform The elongation determined when the maximum load is reached. It applies to materials whose cross-section decreases uniformly along the gauge length up to the maximum load.

elongation unit See **tensile elongation unit.**

elute To remove sorbed materials from a sorbent by means of oil.

e-mail An electronic message that is sent between or among computers and is stored until read or deleted.

embedding Complete encasement in some uniform external shape. Most of the package consists of the plastic. It is a useful technique for protecting and decorating a device or assembly, such as embedding electrical or electronic devices. Protection can be from oxygen, moisture, temperature, electrical flashover, current leakage, salt spray, radiation, solvents, chemicals, microorganisms, mechanical shock, vibration, and so on. Characteristics during embedding that can influence part performance are the stresses that develop between the component and plastic during curing. Differentials between thermal expansion coefficients are a source of poor design and fabricating problems. The design needs to use the appropriate plastic with its processing cycle. The embedment of large components has the risk of runaway exotherms if not properly handled. Also called *casting, potting, injection molding, liquid molding, impregnation,* and *encapsulation.* See **air entrapment; casting; coating, microencapsulation; encapsulation; ferroelectric; impregnation; injection molding, in-mold; injection molding, liquid; insert molding; mold pot; potting.**

embossing **1.** A decorative imprint that is applied to plastics (one or all sides) using different fabricating processes such as extrusion, injection molding, castings, and so on. For example, depressions of a specific pattern on plastic surfaces such as extruded film or sheet are created by using the pattern on rollers with photoengraving. **2.** Providing an embossed surface on molded parts by applying to the mold cavity the desired pattern. See **extruder-roll decorating; mold cavity; roll.**

embossing spanishing A method of depositing ink in the valleys of embossed plastics. Scrappers are used. See **coating, knife; printing.**

embrittlement A condition of low ductility in materials. With certain plastics, such as certain acrylonitrile-butadiene-styrene compounds, embrittlement is due to formation of a vitreous matrix as well as to environmental oxidation of the butadiene particles in the matrix. See **brittleness; hydrogen embrittlement.**

emission See **automotive interior, low-emission plastic; finishing system, reduced-solvent; plasticizer; solvent.**

emission spectroscopy The study of the composition of substances and identification of elements by observation of the wavelengths of radiation that they emit as they return to a normal state after excitation by an external energy source. When atoms or molecules are excited by energy input from an arc or flame, they respond in a characteristic manner. Their identity and composition are signaled by the wavelengths of incident light they emit.

emission spectrum A continuous line spectrum of radiation emitted by a substance.

emission standard See **finishing system, reduced solvent.**

emissivity The ratio of the total heat-radiating power of a surface to that of a black body of the same area and at the same temperature.

emittance The ratio of the radiant flux emitted by a specimen to that emitted by a black body at the same temperature and under the same environment conditions.

empirical Based on experience and observations rather than theory. See **formula, empirical; theory.**

employee invention law See **legal matter: employee/assignment invention.**

employment See **fabricating employment; plastic consumption; productivity; technical writing; World of Plastics Reviews: Challenge 2000: Making Plastics a Preferred Material.**

emulsifying agent An emulsifier that modifies the surface tension of colloidal droplets, keeping them from coalescing and keeping them suspended. It imparts stability by lowering interfacial tension between immiscible liquids that make up an emulsion (one dispersed in the other as droplets). They function as surface-active agents, or surfactants. Although used in small quantities, they can have a significant effect on the surface behavior of a system. Emulsifying materials contain molecules or ions with a hydrophilic group at one end and a hydrophobic group at the other end. There are three basic types: anionic, cationic, and nonionic. Choosing between the types depends on the system to be emulsified, the degree of stability required, and end-use conditions. See **additive; antifogging agent; hydrophilic surface; hydrophobic; latex.**

emulsifying agent, latex See **latex emulsifying agent.**

emulsion A stable dispersion of one liquid in a second immiscible liquid. The stable dispersion generally uses an emulsifying agent that has an affinity for both the continuous and discontinuous phases. Also called *latex.* See **dispersing agent; latex; mill, colloidal; molecule, polar; latex; paint emulsion.**

emulsion/demulsification The process of destroying or "breaking" an unwanted emulsion.

emulsion, paint See **paint emulsion.**

emulsion, photosensitive See **printing, screen photoimage.**

emulsion polymerization See **polymerization, emulsion.**

enamel A type of paint containing binders that form a film by oxidation or polymerization on exposure to air. See **coating; paint; primer.**

enantiomer See **molecule enantiomer.**

encapsulation The enclosing of a part in a closed envelope of plastic by immersing the part (electric, ornament, and other articles) in an unheated or heated casting plastic. Also called *conformal coating.* See **casting; coating, dip; coating, microencapsulation; defoamer additive; electronic chip; exotherm; impregnation, trickle; injection-molding, liquid; medical antibody and antigen, plastic-encapsulated.**

endotherm A process or change that takes place with absorption of heat and requires high temperature for initiation and maintenance as with using heat to melt plastics and then remove heat. Opposite of exotherm. See **ablative plastic; exotherm.**

endothermic Pertaining to a reaction that absorbs heat. Also called *endoergic.* See **ablative plastic.**

endothermic analysis See **thermal analysis.**

endothermic process A process that absorbs heat from the surroundings.

endothermic reaction A reaction that absorbs heat. Opposite of exothermic. In most plastic processes, heat is absorbed to melt plastic. See **ablative plastic; differential scanning calorimetry; pyrolysis.**

endurance Load-carrying ability versus some type of time or performance condition. See **creep; fatigue en-**

durance limit; plastic, long-life; test; thermal endurance.

endurance, thermal See **thermal endurance.**

energy The capacity for doing work or producing change. This term is both general and specific. Generally it refers to the energy absorbed by any material subjected to loading. Specifically it is a measure of toughness or impact strength of a material—for example, the energy needed to fracture a specimen in an impact test. It is the difference in kinetic energy of the striker before and after impact, expressed as total energy per inch of notch of the test specimen for plastic and electrical insulating material [in-lb (J/m)]. Higher energy absorption indicates a greater toughness. For notched specimens, energy absorption is an indication of the effect of internal multiaxial stress distribution on fracture behavior of the material. It is merely a qualitative index and cannot be used directly in design. See **calorimeter; hysteresis heat build-up; joule; radiation; radiation, photon; test, impact.**

energy absorption Generally the energy absorbed by any material subjected to loading; specifically a measure of toughness or impact strength of a material on the energy needed to fracture a specimen in an impact test. See **calorimeter; chemistry, thermo-; kinetic energy dissipated; test, impact.**

energy absorption, megarad One rad is equivalent to an energy absorption per unit mass of 0.01 joule per kilogram of irradiated material; one megarad is 1E + 06 rads. Also called *Mrad.*

energy activation An excess energy that must be added to an atomic or molecular system to allow a process, such as diffusion or chemical reaction, to proceed.

energy and bottles An interesting historical (1950s) example is the small injection blow-molded whiskey bottles that were substituted for glass blown bottles in commercial aircraft (and continue to be used). At that time, just in the United States, over 500×10^{12} Btu—or the amount of energy equivalent to over 80×10^{6} barrels of oil—was reduced per year. See **bottle.**

energy and heat transfer See **thermodynamic property.**

energy and incineration See **incineration and energy.**

energy and plastic Numerous studies have shown (1) plastics consume less energy to fabricate products than other materials, with glass being the major consumer of energy; (2) their use as a product reduces energy consumption; and (3) more energy can be produced when products are incinerated. Without plastic insulation, major appliances such as refrigerators would use up to 30% more energy. Improvements made in energy efficiency through the use of plastics in the last decade saved more than 53 billion kilowatt-hours of electricity annually in the United States. This saves consumers more than $4 billion each year. See **energy; energy and bottles; incineration and energy; petrochemicals; recycling, energy saver.**

energy and recycling, chemical See **recycling, chemical.**

energy, biodegradable See **biodegradable waste.**

energy calorimeter See **calorimeter.**

energy conservation Much less energy is used to produce plastics than probably any other commercial material. Compared to polyethylene plastic, steel requires about three times as much energy, copper 18, and aluminum almost 10. When examining energy consumption or loss, the equipment used in the complete production line as well as the use of plastic products is involved; plastics require less energy particularly when compared to glass. Plastics are major contributors to energy conservation in building insulation and reduced-weight automobiles, for example. On incineration, plastics provide much more energy that can be put to work. See **auxiliary equipment; conservation of matter, law of; energy loss, machine; incineration and energy; mold-filling monitoring; pipe, geothermal; recycling, chemical.**

energy consumption The plastics industry consumes about 3% of the U.S. total annual oil and gas consumption, but this use is more than offset by the savings that plastic products create. Many different studies have substantiated this fact. Worldwide some areas have lower consumption, and others possibly reach up to 4%. See **British thermal unit; calorie; economical control of equipment; extruder drive-energy consumption; heat; oil and gas; recycling energy consumption.** In comparison with other materials, plastics have the lowest specific energy requirements for their manufacture and the lowest recycling energy consumption.

energy content For plastics, fossil fuels serve not only as sources of process energy but as feedstocks. The energy content of plastics is expressed as a percentage of cost—13.2%. This makes it a more crucial cost factor for plastics than for paper (7.9%) or metal cans (7.3%). In times of rising energy costs, the competitiveness of plastics diminishes in domestic markets as well as global ones.

energy conversion See **antiparticle.**

energy cost See **cost, energy.**

energy deformation The energy that is required to deform a material by a specified amount. It is the energy per unit volume that is lost in each deformation loading cycle. Energy loss is the hysteresis loop area, calculated with reference to the coordinate scales. See **hysteresis; stress-strain curve.**

energy demand See **oil and gas.**

energy deposition See **radiation dosimeter.**

energy dissipated See **damping, mechanical.**

energy, electrical See **chemistry, electro-.**

energy efficiency The use of plastics leads to the saving of raw material and energy in several respects. A very large portion of plastics production is processed into long-lived industrial and consumer goods such as heat insulation, furniture, building products, and aircraft parts. Much of the consumer output, such as bottles, can be recycled. Plastic products that are discarded and incinerated as waste can contribute a higher heat value than other materials and thus assist the improved production of electricity or the raising of steam in boilers. The approximate calorific value of various materials [kj/kg (Kcal/Kg)] follows: 46,000 (11,000) polyethylene or polystyrene, 44,000 (10,500) heating oil, 38,000 (9,000) fats, 30,000 (7,000) wood, 19,000 (4500) polyvinyl chloride or leather, 17,000 (4,000) paper, and 16,000 (3,800) wood. See **energy consumption; incineration; market; pipe, geothermal; plastic material type; recycle.**

energy flow See **thermodynamic property.**

energy, free Energy that is available to do useful work during processing. Free-energy change for a process that is carried out at a constant pressure and temperature is used to predict the spontaneity of the process.

energy, heat See **damping capacity; enthalpy; molar heat of sublimation; molar heat of vaporization.**

energy input, machine The usual plasticator processing machine (extruder, injection molding, etc.) requires most of its energy to be applied to the plastic (possibly 40 to 60%) with motor drives at 10 to 20%. The remainder is in barrel heat and cooling, water circulation, instruments, and other rather minor sources.

energy ionization The minimum energy required to remove an electron from its ground state in an atom to infinity. See **ionization.**

energy, kinetic $\frac{1}{2} mv^2$, where m = mass in lb (kg) and v = velocity in ft/s (cm/s). See **energy, law of conservation of.**

energy lattice The energy required to separate completely 1 mole of a solid ionic substance into gaseous ions. See **ion.**

energy, law of conservation of The principle that energy is neither created nor destroyed. Energy is simply transferred from one form to another. Potential energy is the possible work that a mass can perform. It is further defined as a state where a substance has energy and needs a reactant to transfer that potential energy to kinetic energy, which is the actual work being performed by energy. In the case of burning a material, fire is the reactant. Kinetic energy in this case is heat. If this heat energy is captured, it can be used to heat other materials and convert the kinetic energy to pressure energy, which will actually perform a working function. For pneumatic conveying, kinetic energy is defined as the energy retained by a mass due to its velocity. Pressure energy is the energy of a fluid that actually performs a working function at a pressure above atmospheric pressure. See **chemistry, thermo-; energy, kinetic; thermodynamic property.**

energy loss See **energy deformation.**

energy loss, machine Every machine can be pictured thermodynamically as an open system with a complex working medium having interim phase transitions, particularly the transition from the plastic solid to the melted or fluid condition. A continuing effort is under way by equipment manufacturers to reduce energy consumption as well as energy loss. In comparison with other materials, plastics have the lowest specific energy requirement for their manufacture and their fabrication products and the lowest recycling energy consumption. Energy conservation can be considered from several viewpoints that range from producing plastic to processing to recycling products. In practically all evaluations, utilization of plastics saves or reduces energy requirements. In automobiles, aircraft, and other means of transportation the increasing use of plastics reduces weight and fuel consumption (an old example is the replacement of the small glass whiskey bottles aboard aircraft with extruded blow-molded plastic bottles and the resulting fuel energy savings). Using plastics in construction saves by insulation gains. Just shipping the lighter-weight plastic products saves energy. And the list continues. See **drive-system control; electric motor, adjustable-speed-drive; electric motor drive; energy input, machine; extruder drive-energy consumption; injection-molding machine electrical operation.**

energy, mechanical See **resilience, impact.**

energy melt heat transfer See **thermodynamic property.**

energy moderator A substance that can reduce the kinetic energy of neutrons.

energy output See **British thermal unit; energy reclamation.**

energy, plastic drying See **drying.**

energy, plastic work It is the energy expended in performing plastic deformation. By an analysis of plastic work, similar to that of thermodynamic theory such as rubber elasticity, the stress-strain relationships for deformation may be derived taking into account the change in strains occurring. See **deformation, elastic; stress-strain curve; thermodynamic property.**

energy, potential See **energy, law of conservation of.**

energy, pressure See **energy, law of conservation of.**

energy, quanta See **electromagnetic radiation quanta energy.**

energy, radiant Energy transmitted as electromagnetic waves. See **absorption line; spectrum.**

energy reclamation Plastics are suitable for thermal energy reclamation or recycling because their energy content or heat value is higher than materials such as coal. Often their heat value is in the order of heating oil. For these reasons it is rational and logical to reuse plastic wastes by energy reclamation that are not suitable for recycling, chemical thermal reclamation, and so on. In waste incineration plants, energy is obtained in the form of community heat and electrical power. Practically all the plastics can be incinerated without problems and with a low (controllable and confining) emission of pollutants. For certain plastics such as halogenated PVC, special available systems can be used to permit incineration. See **carbonaceous matter; design source reduction; incineration; landfill and degradation; recycling, chemical; waste.**

energy recovery, waste See **energy reclamation; refuse-derived fuel.**

energy, shear See **screw shear rate.**
energy, solid waste See **British thermal unit.**
energy spectrograph, x-ray fluorescence See **spectrograph, x-ray fluorescence.**
energy state, excited See **atom energy state, excited.**
energy, thermal See **ablation.**
energy, thermal analysis See **thermal analysis, enthalpimetric.**
energy, thermal reclamation See **energy reclamation.**
energy transmission See **thermal diffusivity.**
energy, unavailable See **entropy.**
energy, van Hoff isotherm An equation for the change in free energy during a chemical reaction, the temperature, and the concentration and number of molecules in the reactants. See **isotherm.**
Engel coating process See **coating, Engel process.**
engine See **automotive plastic engine.**
engineer A problem solver who is thrust into society's challenges and called on to bridge theory-application-science-technology-practicalities and meet the world's needs without despoiling the environment. See **computerized knowledge-based engineering; risk assessment.**
engineered die See **die, preengineered.**
engineered mold See **mold, preengineered.**
engineered, re- A concentrated and targeted product that is in production or the final prototyping stage and can be produced at a lower cost and still meet the same performance requirements. Reengineering involves factors such as designing, engineering, material and process evaluation, production procedure, and even cost and marketing strategy. Whatever action is taken, the basic analysis takes into account all factors as they apply to value analysis and are summarized in the FALLO approach. See **electronic data interchange; FALLO approach; production data acquisition; quality cost overview; value analysis.**
engineering and processing See **plastics and the future.**
engineering approach versus practical approach With the practical approach, most plastics are required to withstand only short-term static mechanical loads—that is, no dynamic loads. Thus, conventional short-term static tests generally suffice. The engineering approach recognizes that many plastic products have been used since their inception to take long-term dynamic or static loads. Thus, they consider fatigue, torsion, creep, and other data that include plastic's viscoelastic properties. See **kiss; plastic processing.**
engineering, chemical reaction See **exotherm; reactor technology.**
engineering design See **design, engineering; design, mechanics of; design, Poisson's ratio in; risk, acceptable.**
engineering dimensional property See **dimensional property.**
engineering, genetic Genetically altering microbes to make them especially efficient in degrading specific types of contaminants in plastics. See **biodegradable.**
engineering graphic See **graphic character.**
engineering judgment See **design analysis.**
engineering, macromolecular See **designing with plastic tailor-made models.**
engineering material A material (such as plastics, metals, aluminum, glass, etc.) that is usually characterized by high strength and stiffness, dimensional stability, and so on. Materials tend not to be commodity materials, even though some commodity materials (such as rocks, sand, and wood) involve being used as engineering materials. See **commodity plastic; engineering plastic.** Engineering materials are depicted as solids formed from various elements. A solid material can be a pure element such as gold, a compound such as sand of silicon and oxygen (SiO_2), or a combination of molecules such as plastics. See **element.**
engineering plastic A plastic that has higher performance properties or has specialty characteristics when compared to commodity plastics. There is no absolute definition of an engineering plastic. When engineering plastics have increased production capacities, they become commodity plastics. Many plastics cross over into both categories. An example goes back to 1868, when thermoplastic cellulose nitrate was developed. When used to make billiard balls, it was very much an engineering plastic displaying high impact and low deformation. When used as motion picture film (celluloid) or as an automobile window (later replaced by PVB), it became a commodity plastic. See **commodity plastic; designing with the pseudo-elastic method; metal, light; periodic table; plastic, advanced.**
engineering problem See **problems and solutions; statistical data collection.**
engineering, reactor See **reactor technology.**
engineering safety See **safety, engineering.**
engineering stress See **stress.**
engineering value analysis See **value analysis.**
engineering writing See **technical writing.**
engineering yield strength See **stress, offset yield.**
engineer, plastic An engineer who is knowledgeable in plastics. See **productivity.**
engraved roll coating See **printing, gravure.**
engraving See **printing, photoengraving.**
EnPlot software ASM's analytical engineering graphics software that is used to transform raw data into meaningful, presentation-ready plots and curves. It offers users a wide array of mathematical functions that are used to fit data to known curves and includes quadratic Bezier spline, straight-line polynomial, Legendre polynomial, *n*th order, and exponential splines. See **computer software; mathematics.**
enthalpy The quantity of heat that is equal to the sum of the internal energy of a system plus the product of the pressure-volume work performed on the system such as the action during heat processing of plastics. As a thermo-

dynamic function, it is defined by the equation $H = U + PV$, where H = enthalpy, U = internal energy, P = pressure, and V = volume of the system. See **heat of activation; thermal data; thermodynamic property.**

enthalpy, Hess's law The principle that is overall enthalpy change in a reaction is equal to the sum of enthalpy changes for the individual steps.

enthalpy of formation, standard The heat exchange that takes place when a pure substance is formed from its elements at 1 atm.

enthalpy of reaction The heat change that accompanies a chemical reaction when it is run at constant pressure. It is the difference between the enthalpies of the products and the enthalpies of the reactants. See **chemical reaction.**

enthalpy of transition The change of enthalpy that accompanies a phase transition.

entrepreneur Entrepreneurs, or new business risk takers, have brought the plastics industry to profitable ventures worldwide. See **Japanese workmanships; plastic competition; productivity; risk, acceptable; World of Plastics Reviews: Thinking Like a Manager, and Managing for the Long Run.**

entropy A measure of the unavailable energy in a thermodynamic system, commonly expressed in terms of its exchanges on an arbitrary scale with the entropy of water at 0°C (32°F) being zero. The increase in entropy of a body is equal to the amount of heat absorbed divided by the absolute temperature of the body.

entropy of activation The difference in entropy between the activated complex in a chemical reaction and the reactants. See **thermodynamic property.**

entropy of mixing After mixing substances, the difference between the entropy of the mixture and the sum of the entropies of the components of the mixture.

entropy of transition The heat absorbed or liberated in a phase change divided by the absolute temperature at which the change occurs.

envelope See **structural envelope.**

envenomation See **deterioration, envenomation.**

environment All the different conditions that externally exist around a product and influence the performance of products. You name it, and that condition exists, such as temperature, humidity, water, ozone, oxygen, nitrogen, atmospheric pressure, earthquake, tornado, radiation, magnetic and electric fields, impact, vibration, people (lipstick, perfume, soap, etc.), food, animal, salt and fresh water, war, and so on. See **antimicrobial agent; antioxidant agent; bacteria; biodegradable; biodegradable waste; colorant; deodorant additive; geomembrane; ISO-14000 certification; landfill and degradation; medical materials and the environment; pigment; plant environment; plastics cradle-to-grave; recycling and lifecycle analysis; transducer environment; zirconium.**

environmental and economic sustainability, building for See **vinyl composition tile.**

environmental assessment A document usually prepared by a private consulting firm under the National Environmental Policy Act to determine whether an action in the plant would affect the environment and require a more detailed statement on the environmental impact.

environmental condition See **electromagnetic compatibility; reliability.**

environmental impact statement A document that describes the positive and negative effects of an action required of federal agencies for projects or legislative proposals that would affect the environment.

environmental risk See **polychlorofluorocarbon; risk, acceptable.**

environmentally acceptable coating, ink, adhesive reliability With increasingly stringent regulations governing the emission of toxic pollutants, the technology and raw materials that are used in formulations of environmental coatings, inks, adhesives, fillers, and so on have been undergoing significant changes. Raw materials have become more specialized and sometimes more costly; new markets are developing. Latex formulations account for the majority of value and consumption in these materials—80wt% and 66% cost. The remainder is principally polyurethanes, epoxies, polyesters, and acrylics. See **adhesive; coating; ink; printing ink.**

environmentally friendly additive An additive that meets environmental requirements. Examples include colorants and pigments (heavy metals are being phased-out), foaming agents (chlorofluorocarbon being eliminated), flame retardants (polybrominated diphenylether being reduced, etc.), and others. See **additive; foam and blowing agent.**

environmental quality standard See **ISO-14000 certification.**

environmental stress cracking (ESCR) Cracking or crazing that occurs in a thermoplastic subjected to stress or strain in the presence of certain weather conditions or chemicals or as a result of aging. Also called *solvent cracking*. See **crack; orientation, accidental; stress crack; stress whitening.**

environment and color See **colorant.**

environment and ocean From ships to submarines to mining at sea bottom, certain plastics can survive the sea environments, which are considered more hostile than those on earth or in space. The U.S. Navy has conducted extensive tests on different materials, including plastics, and people. See **marine applications for plastics; water, desalinizing ocean.**

environment and public opinion Because the strength of public opinion is a strong weapon, sometimes it is easier to remove products from the market than to fight a court battle. For example, McDonald's decided in November 1990 to drop its polystyrene plastic foamed clamshell hot food container. Even though it had made a thorough and successful study and evaluation (recyclability, flammability, performance, safety, handling, etc.), grade school students (in California and Massachusetts), encouraged by their teachers, succeeded in persuading McDonald's to drop the clamshell (only in the United States) since it did not want to develop a public relations image problem. Worldwide, McDonald's continued to use PS since it was more efficient in many ways (cleanliness, safety, recyclable, etc.). See **foam; plastic and pollution; plastic myth and fact; recycling; waste.**

environment, work See **Preface: World of Plastics Reviews: Thinking Like a Manager**

enzyme catalyst See **catalyst, enzyme; zymoplastic.**

epichlorohydrin rubber The basic epoxidizing plastic intermediate that is used in the production of epoxy plastics.

epoxide plasticizer A group of plasticizers that is derived by the reaction of epoxide with hydrogen peroxide and natural vegetable oils or fatty acids. Heat and light stability are their most important characteristics.

epoxide stabilizer A compound that is used as a stabilizer.

epoxy plastic A thermoplastic or thermoset epoxy plastic that occurs in liquid or solid form and that can be processed with or without heat and pressure. With their exceptional properties, they have diversified and useful applications. Examples in the thermoset plastics are the matrix high-performance reinforced plastics and adhesives. See **adhesive, reactive-component; bisphenol-A; reinforced-plastic material.**

equation See **designing with the pseudoelastic method; formula; ionic equation, net; mathematical equation.**

equilibrium A static or dynamic state of balance between opposing forces or actions.

equilibrium amplitude The maximum displacement of material or product as measured from its equilibrium position.

equilibrium centrifugation In the science of resinography, a method for determining the distribution of molecular weights by spinning a solution of the specimen at a speed such that the molecules of the specimen are not removed from the solvent but are held at a point where the centrifugal force tending to remove them is balanced by the disperse forces caused by the thermal agitation. See **molecular weight distribution; molecular weight distribution resinography; resinography.**

equilibrium constant A number equal to the ratio of the equilibrium concentrations of products to the equilibrium concentrations of reactants, each raised to the power of its stoichiometric coefficient.

equilibrium diagram See **alloy constitutional diagram.**

equilibrium, heterogeneous **1.** A state of equilibrium between reactants and products that are in different phases. **2.** The point at which the vapor, liquid, and solid states of a substance are in equilibrium. See **mixture, heterogeneous; nucleation, heterogeneous; plastic material, heterogeneous.**

equilibrium vapor pressure The vapor pressure of a liquid when the rates of evaporation and condensation are equal. See **Raoult's law.**

equipment See **auxiliary equipment; capital equipment investment; fabricating processing type; FALLO approach; gross domestic product; operation, manual; operation, semiautomatic; operation, automatic; plastic-industry machine sales; World of Plastics Reviews: The Plastics Industry; World of Plastics Reviews: Basics and Overviews of Fabricating Processes.**

equipment consumption See **plastic consumption.**

equipment customized Equipment that is designed and manufactured to meet certain specific requirements.

equipment downstream See **auxiliary equipment.**

equipment, control of See **capital equipment investment; economical control of equipment.**

equipment, interrelate See **World of Plastics Reviews: The Plastics Industry.**

equipment lockout See **safety, machine-lockout.**

equipment lubrication See **lubricant.**

equipment operation See **operation, automatic; operation, manual; operation, secondary; operation, semiautomatic.**

equipment sales See **plastic industry size.**

equipment startup and shutdown See **fabricating startup and shutdown.**

equipment upstream See **auxiliary equipment.**

equipment variability See **plastic material and equipment variable.**

equivalence point See **chemical-reaction equivalence point.**

equivalent The amount of substance that gains or loses a substance such as one mole of electrons in a redox reaction. See **redox plastic.**

equivalent mass The mass, in grams, of a substance that gains or loses one mole of electrons in a redox reaction.

erosion See **cavitation; corrosion resistance; porosity.**

eraser A device that removes pencil or ink from paper. The potential of an eraser was first suggested in 1754 in the Proceedings of the French Academy. The first patent on a one-piece pencil and eraser was issued in the United States to J. Rechendorf of New York City on March 30, 1758. See **rubber, natural.**

ergonomics The science of work. It is the key to designing better workplaces—situations where tools, task, and user come together with a minimum of stress.

erosion The removal of material due to some type of erosion by sand, water, chemicals, environment, and so on. See **ablation; abrasion; cavitation erosion; corrosion; electrical erosion breakdown; electroerosive cutting and sinking; frettage; galling; geomembrane; geotextile; rain erosion; rust; spalling.**

erosion behavior, brittle Erosion behavior that has characteristic properties that can be associated with brittle fracture of the exposed surface, particularly with metals. In solid impingement an easily observable aspect of erosion helps to distinguish brittle from ductile behavior. This is a manner in which volume removal varies with the angle of attack. With brittle erosion the maximum volume removal occurs at an angle near 90° in contrast to about 25° for ductile erosion behavior. See **brittle.**

erosion, cavitation See **cavitation erosion.**

erosion, ductile behavior Erosion behavior that has the characteristics of metal properties and that can be associated with ductile failure of the exposed solid surface. Considerable "plastic" deformation precedes or accompanies material loss from the surface that occurs by gouging or tearing with eventual embrittlement through work hardening that leads to crack formation. This type of erosion is sometimes associated with plastic materials.

erosion-electrical breakdown See **electrical erosion breakdown.**

erosion, rain See **rain erosion.**

error **1.** The substitution of one character for another. See **mathematical closure error. 2.** The departure between the true and stated value of a process variable. A positive error denotes that the indication of the instrument is greater than the true value. **3.** See **mathematical closure error; problems and solutions; statistical randomization; training and quality.**

error, bias A systematic error in contrast to a random error.

error, noncumulative See **repeatability.**

error of the first kind The rejection of a statistical hypothesis when it is true.

error of the second kind The acceptance of a statistical hypothesis when it is false.

error, percentage A range (100%) of the difference between indicated value and true value; or maximum scale of an instrument.

error, random The chance variation encountered in all experimental work despite the closest possible control of variables. It is characterized by the random occurrence of both positive and negative deviations from the mean value for the method, the algebraic average of which will approach zero in a long series of measurements. See **precision.**

error randomization The procedure used to allot treatments of random to the experimental units to provide a higher degree of independence in the contributions of experiment error to estimates of treatment effects.

error randomization statistically See **statistical randomization.**

error, residual The difference between the observed result and the predicted value.

error, standard A measure of the uncertainty of the average of a number of replicate measurements. See **deviation, standard.**

ESCR See **environmental stress cracking.**

ester The reaction product of an alcohol and an acid.

ester gum plastic A plastic made from rosin or rosin acids and a polyhydric alcohol, such as glycerin or pentaerythritol.

estimating cost See **cost estimating.**

etching A controlled preferential attack on a surface of a material. See **chemical etching; chemical milling; photoetching tool steel; surface treatment.**

ether One of a class of organic compounds in which any two organic radicals are attached directly to a single oxygen atom; compounds with the R-O-R, where R is either an alkyd or an aryl group.

ether-oxide plastic A common name for a number of industrially important plastics that specifically include the words *ether* or *oxide,* which reflects the presence of an ether or oxide linkage (-0-) in the backbone of the repeat unit. Plastics include acetal and polyphenylene ether. See **acetal plastic; organic; polyphenylene ether plastic.**

ethics Although there is no substitute for individual action based on a firm philosophical and ethical foundation, designers and processors have developed guidelines for professional conduct based on their experiences with troublesome situations. These guidelines are provided by various industry and technical societies. See **Unwritten Laws of Engineering, The.**

ethnic plastic See **plastic, ethnic.**

ethyl acetate A solvent for certain plastics such as coatings.

ethyl alcohol A solvent for plastics and oils, cleaning compositions, antifreeze, automotive fuel additives, alcoholic beverages, and so on. See **alcohol, absolute.**

ethyl benzene A colorless liquid that boils at 136°C and is insoluble in water. It is used in organic synthesis, as a solvent, and in making styrene.

ethyl cellulose plastic See **cellulose ethyl plastic.**

ethylene C_2H_4 is a colorless, flammable gas obtained from cracking petroleum or natural gas hydrocarbons. It is used as the monomer in polymer synthesis and anesthetics. Also called *ethane* or *olefiant.*

ethylene-acrylate (copolymer) rubber (EAR) A family of elastomers that provide high resistance to ozone; better energy absorbers than butyl rubbers; toughness with flexibility; good temperature properties; resistance to deterioration due to heat, oil, and water; environmental stress-cracking resistance; and compatibility with many different fillers and other plastics. Rubber copolymers of ethylene acrylates are identified as acrylic ethylene rubber, EAR, EA, and so on. See **Wacker process.**

ethylene acrylic elastomer (EA) A moderately priced thermoplastic that is heat and fluid resistant but is surpassed by expensive types such as fluorocarbons and fluorosilicones. A special feature of the EAs is their nearly constant damping characteristics over a broad range of temperatures, frequencies, and amplitudes. See **damping.**

ethylene chlorotrifluoroethylene copolymer plastic A thermoplastic that has strength, creep resistance, and wear resistance significantly greater than those of other fluoroplastics. It also has good dielectric properties, has very high chemical resistance at room and elevated temperatures, resists ignition and flame propagation, and has a service temperature from cryogenic to 170°C (338°F).

ethylene dichloride (EDC) A substance that is produced by either direct chlorination or oxychlorination of ethylene. Polyvinyl chloride via vinyl chloride monomer is the primary end use for EDC.

ethylene-ethyl acrylate plastic (EEA) One of the copolymers of LDPE such as ethylene-methacrylate and ethylene-vinyl acetate. EEA has high heat resistance, flex-resistance, and low temperature flexibility. It is used in electrical cables. As a film, it is not as transparent as EVA.

ethylene glycol (EG) A clear, colorless, syrupy liquid that is hygroscopic and soluble in water and alcohol. It is used as a coolant, an antifreeze, and in polyester products (fibers, films, etc.). It is used in mold cooling when the mold is operating just above and below 0°C (32°F) to prevent the freezing of the usual water coolant, which cannot operate at these low temperatures. See **calcium chloride; coolant; mold cooling; mold-cooling temperature; mold heating.**

ethylene methyl acrylate copolymer plastic A thermoplastic that has good dielectric properties, toughness, thermal stability, and resistance to environmental stress cracking.

ethylene n-butyl acrylate copolymer plastic (EnBA) A substance that is principally used as a heat-seal or tie-layer in coextruded films and coatings for food and industrial packaging. Also called *ethylene butyl acrylate* (EBA).

ethylene oxide (EtO or EO) A highly reactive chemical that is used in the manufacture of ethylene glycols, surface active agents, polyether polyols, and so on. See **sterilization, ethylene oxide.**

ethylene plastic A plastic that includes ethylene homopolymers and copolymers with other unsaturated monomers. They are very important to olefins such as polyethylene, polypropylene, and polar substances such as vinyl acetate. Their properties and uses depend on their molecular structure and weight. They produce many different and useful types of plastics to the industry. Usually called *polyethylene plastic.* See **molecular structure; molecular weight; polyethylene plastic.**

ethylene-propylene copolymer plastic (P(E-P)) A plastic that can have a small proportion of PP-type repeat units that can be used to lower the crystallinity of linear polyethylene. When large amounts of comonomer are used, two commercially important copolymers result—namely, polyallomers and EP rubber.

ethylene propylene plastic A fully saturated chemically inert copolymer. This thermoset plastic is cured with a peroxide catalyst. These elastomers are somewhat similar to natural rubber. Also called *ethylene propylene rubber* (EPR). See **benzoyl peroxide.**

ethylene propylene-diene monomer plastic (EPDM) A thermoset that is vulcanized using sulfur. It has excellent resistance to oxygen, ozone, light, high and low temperatures, acids, alkalies, and oils. It is used in other elastomers and plastics as an impact modifier and also to improve heat and ozone resistance. Also called *EPDM rubber.*

ethylene-styrene interpolymer plastic (ESI) Dow's ESI has unusual mar resistance and a "self-healing" ability that makes scratches disappear. Metallocene-catalyzed ESI can range from flexible to rigid, depending on monomer ratio, with little or no need for a plasticizer. An application targeted includes calendered flooring to replace flexible PVC and impact modifier for PS. See **catalyst, metallocene.**

ethylene-tetrafluoroethylene plastic (ETFE) A tough translucent thermoplastic material with a high impact resistance and useful mechanical properties from cryogenic temperatures to 180°C (356°F). It provides a continuous service temperature from about 155° to 190°C. Its chemical resistance, electrical properties, and weather resistance are similar to those of ECTFE and approach those of fully fluorinated plastics. ETFE melts and decomposes on exposure to flame.

ethylene-vinyl acetate plastic (EVA) A copolymer that is similar to polyethylenes but has considerably more flexibility and softness. It is used alone, coextruded, or coinjected. EVA parts have good clarity and gloss, stress-crack resistance, barrier properties, low temperature toughness, adhesion capabilities, resistance to ultraviolet radiation, and little or no odor; they retain their flexibility at low temperatures and are U.S. Food and Drug Administration approved. Their main limitation is their comparatively low resistance to heat and solvents. However, alcohols, glycols, and weak organic acids do no damage.

ethylene vinyl alcohol plastic See **polyethylene-vinyl alcohol plastic.**

Euler equation A special case of the general equation of motion. It applies to the flow systems in which the viscous effects are negligible. See **flow; viscous.**

Euromap A trade association that represents the European plastics and rubber machinery markets. See **communication protocol; test, white-box and black-box.**

European article number (EAN) The international barcode for retail food packaging. See **barcode.**

eutectic A mixture of two or more substances that solidifies as a whole when cooled from the liquid state, without changing composition. It is the composition within any system of two or more crystalline phases that melts completely at the minimum temperature. See **eutectic mixture.**

eutectic arrest In a cooling (or heating) curve, an approximately exothermal segment that corresponds to the time interval during which the heat of transformation from the liquid phase of two or more conjugate solid phases is being evolved (or conversely).

eutectic composition The state of having a minimum melting temperature when two or more liquid solubility curves interact.

eutectic deformation The composition within a system of two or more components, which on heating under specified conditions develops sufficient liquid to cause deformation at the minimum temperature.

eutectic divorced Having components of a eutectic mixture that appear to be entirely separate.

eutectic mixture The composition within any system of two or more crystalline phases that melts completely at a relatively low temperature and can be repeatedly solidified and melted. Two or more substances solidify (such as zinc-aluminum, tin, bismuth, etc.) as a whole when cooled from the liquid state without changing composition. They have been used rather extensively since at least the 1940s during certain plastic processing techniques such as injection molding, casting; reinforced plastic bag molding, and compression molding. See **soluble-core molding; casting, investment; extruder liquid-curing-medium process; extruder wire and cable process; metal, white.**

eutectic temperature The melting temperature of an alloy with a eutectic mixture. It is at the interaction of two or more liquid solubility curves.

evaluation, economic See **economic evaluation.**

evaluation, mixing See **mixing evaluation.**

evaporation The escape of molecules from the surface of a liquid. Also called *vaporization.*

evidence, circumstantial See **legal matter: circumstantial evidence.**

evolutionary developments See **revolutionary versus evolutionary developments.**

evolutionary versus revolutionary technicalwise See **microsphere; strip; volatile loss.**

Exact Exxon Chemical Co.'s trade name for its family of polyolefin branched linear copolymer.

exfoliation See **vermiculite.**

exhibitor shows See **shows and conferences.**

exotherm The temperature versus time curve of a chemical reaction or a phase change giving off heat, particularly the polymerization of thermoset plastics. Maximum temperature occurs at peak exotherm. Some plastics such as room-temperature-curing thermoset polyesters and epoxies will exotherm severely with damaging results if processed incorrectly. As an example, if too much methyl ethyl ketone peroxide catalyst is added to polyester plastic that contains cobalt naphthenate (promoter), the mix can get hot enough to smoke and even catch fire. Thus, an exotherm can be a help or hindrance, depending on the application, such as during casting or potting. See **casting heat, exothermic; heat; methyl ethyl ketone peroxide; phase change; reaction injection molding; reactor technology; reinforced-plastic lay-up, wet.**

exotherm analysis See **thermal analysis.**

exotherm curve Temperature versus time curves during a curing cycle. Peak exotherm is the point of highest temperature of a plastic during the cure.

exotherm heat The heat that is given off during a polymerization reaction by the chemical ingredients as they react and the plastic cures.

exothermic reaction The temperature rise resulting from the liberation of heat by a chemical reaction. It is the opposite of endothermic reaction. See **chemical reaction; combustion, autoignition point; differential scanning calorimetry.**

expandable honeycomb or foam core See **core, honeycomb or foam.**

expandable mold core See **mold, collapsible-core.**

expandable plastic Primarily, a one-part expanding plastic. Plastics that are used include polystyrene, polypropylene, and nylon. The most popular is polystyrene, where plastic beads (including their gas-blowing agent, pentane) are prepared more accurately sizewise and weightwise than the conventional raw material plastics that are used in most other processes. These beads can be made into cellular foams by thermal, chemical, or mechanical actions. Foamed plastics can be considered the major identification of all cellular plastics, which in turn have subdivisions that meet certain marketable products such as the expandable plastics, structural foams, and so on. See **foam; foam and blowing agent.**

expandable plastic steam molding The process that is used to mold foamed parts from preexpanded beads (PS, PE, etc.) using steam as a source of heat to expand the blowing agent in the plastic. The steam usually is in direct contact with the beads. After preexpansion, the beads go into a closed mold cavity that has many holes (perforated) to provide the final heat expansion of the beads.

expandable polystyrene (EPS) The molding of this material starts with polystyrene solid beads or spheres that contain blowing agents that usually contain the hydrocarbon pentane liquid forming gas. The process starts by preexpansion of the beads by heat (usually steam is the most economical, but others can be used, such as hot air, radiant heat, and hot water). Next, these beads are moved, usually by air, through a tube into an open mold cavity that ranges from simple to complex shapes. This steam-chest mold could vibrate to aid the beads in developing a desired alignment. On closing the mold and applying additional steam heat via perforations in the mold cavity, the final expansion occurs. Another technique has steam probes initially located in the cavity; after steam is applied, the probes are retracted as the beads expand. During expansion the beads melt together, adhering to each other and forming a relatively smooth skin. Pressures required are in the range of 50 psi (0.35 MPa) allowing the use of low-cost aluminum molds. After the heat cycle, the water flood cooling cycle starts. Because the EPS is an excellent insulator it takes a longer time to cool than a solid plastic part does. Cooling can be in the same steam chamber by directing water sprays on the closed mold; spray is more effective than water flood cooling. See **foam; mold cooling, flood; pentane gas.**

expandable polystyrene block molding Blocks, also called *buns,* of EPS density are normally 1 to 1½ lb/ft^3 (16 to 24 kg/m^3). Special machines are used to produce blocks that can be at least 12 to 24 in. (30½ to 61 cm) thick, 4 ft (1.2 m) wide, and from 8 to 16 ft (2½ to 5 m) long. See **foam.**

expandable polystyrene density An outstanding characteristic of EPS is its extremely low to high density range (at least 0.75 to 10 lb/ft^3 (12 to 160 kg/m^3)) of products that can be molded to rather tight density tolerance.

expandable sheet stock See **foamed sheet stock.**
expander roll See **extruder roll, spreader/expander.**
expansion coefficient See **coefficient of expansion; coefficient of linear thermal expansion.**
expansion, linear An increase of a given dimension that is measured by the expansion of a part or component subject to a controlled temperature gradient. See **coefficient of linear thermal expansion.**
expense See **cost.**
experiment See **design, experiment.**
expert witness See **legal matter: expert witness.**
explosive limit The minimum or maximum concentration of a substance in air that will propagate an explosion.
extended pigment See **pigment, extended.**
extender A relatively inexpensive plastic, plasticizer, pigment, or filler (such as calcium carbonate and talc) that is used to reduce the amount of the primary plastics or improve processing of plastics, rubbers, and coatings, thus reducing cost of material without significant reduction in properties. Also called *plasticizer, diluent,* or *filler.* See **additive chain extender; coumarone-indene plastic; filler; pigment; pigment, extended; plasticizer; plasticizer extender.**
extender blender See **plastisol blending extender plastic.**
extender plasticizer See **plasticizer, secondary.**
extender, plastisol See **plastisol blending extender plastic.**
extensibility The ability of a material to extend or elongate on application of sufficient force, expressed as a percent of the original length. See **elongation.**
extensional-bending coupling See **reinforced-plastic extensional-bending coupling.**
extensometer See **strain extensometer.**
extractable See **biocompatibility.**
extractor **1.** A device for removing a molding from a mold. See **mold ejector; part handling equipment; plasticizer exudation; exudation.** **2.** A container or machine such as a centrifuge for extracting ingredients from a mixture.
extrudate The plastic hot melt as it emerges, discharges, or exits from the extruder die's orifice into a desired product form, such as film, sheet, coating, or pipe.
extrudate drool See **die drip.**
extrude The material that exits the extruder die that forms products such as film, sheet, or pipe. See **extruder.**
extruder A machine that feeds thermoplastic plastics (solid forms to liquids) through a plasticator (barrel and screw), melting the plastic and pumping it through a die's orifice (opening). The extrusion processes offer the advantages of versatile plastic processing techniques that are unsurpassed in economic importance by any other process. Many different types have been designed for over a century to meet the variety of plastic products that are produced. Practically all have a plasticator (screw/barrel) in the horizontal position. Extruders now consume about 36wt% of all plastics processed and represent the consumption of more plastics processed than any other. They include principally controlled rotating single- and twin-screw designs. The action between the plasticator screws and barrels basically provides the shearing (heating) action of the plastic. Extruders can be classified as (1) continuous with single screws (single and multistage) or multiscrews (twin-screw, etc.); (2) continuous disk or drum, which uses viscous drag-melt actions (disk pack, drum, etc.) or elastic-melt actions (screwless, etc.); and (3) discontinuous, which uses ram actions (very low-viscosity thermoplastics, thermoset plastics, and rubbers/elastomers) and reciprocating actions (injection molding, etc.). The extruders form a homogeneous plastic melt and force it through a die orifice that relates to the shape of the product's cross-section. The formed TP melt (extrudate) is cooled as it is being drawn away from the die exit through downstream equipment. Products produced include films, sheets, profiles, pipes, tubes, rods, wire and cable coverings, coatings, filaments, blown shapes, and others. See **binder; clean-area fabricating; die pressure; extrusion.**
extruder adapter, in-line The die and extruder are on the same line, and the extrudate is centered on the extrusion barrel. See **adapter system.**
extruder, adiabatic A process or transformation in which no heat is added to or allowed to escape from the system under consideration. The term is used, somewhat incorrectly, to describe a mode of a process such as an extruder in which no external heat is added to the extruder. Heat may be removed by cooling to keep the output temperature of the melt passing through the extruder at a constant and control rate. The heat input in such a process is developed by the screw as its mechanical energy is converted to thermal energy. Also called *autothermal.* See **adiabatic; extruder, autogenous.**
extruder air gap The distance from the die opening to the first downstream equipment such as nip rolls (pressure roll and the cooling roll).
extruder angle-head adapter During angle-head extrusion, the adapter swings the melt through a 45° or 60° bend.
extruder artificial intelligence See **intelligence, artificial.**
extruder, autogenous An extruder that operates without forced cooling or heating. This is the *autogenous extrusion operation,* which is not to be confused with an *adiabatic extruder.* In an autogenous process, the heat required is supplied entirely by the conversion of mechanical energy into thermal energy. However, heat losses can occur in an autogenous process. In an adiabatic process, there is absolutely no exchange of heat with the surroundings. An autogenous extrusion operation can never be truly adiabatic but only approximates it. In practice, autogenous extrusion does not occur often because it requires a delicate balance between plastic properties, machine design, and operating conditions. A change in any of these factors will

generally cause a departure from autogenous conditions. The closer one operates to autogenous conditions, the more likely it is that cooling will be required. Given the large differences in thermal and rheological properties of plastics, it is difficult to design an extruder that can operate in an autogenous fashion with several different plastics. Therefore, most extruders are designed to have a reasonable amount of energy input from external barrel heaters. See **extruder, adiabatic.**

extruder auxiliary equipment See **auxiliary equipment.**

extruder back pressure See **back pressure.**

extruder back pressure-relief port An opening in an extruder die that allows excess material to escape.

extruder, Ballatini process A process by which nonwire extrusions may be continuously vulcanized by feeding the extrudate to a high-temperature fluidized bed of tiny glass beads. Heat transfer is better than that of hot-air ovens but not as efficient as the liquid-curing-medium (LCM) extruder. Like the LCM and air oven, the Ballatini method is a zero-pressure process in which the forces per unit area on the surface of the extrudate are minimal. The fluidized-bed method of vulcanization is also used for the manufacture of hose. See **extruder liquid-curing-medium process; extruder wire and cable; fluid-bed process; sintering; vulcanization.**

extruder barrel See **barrel, extruder and injection-molding; coating, fluidized-bed.**

extruder barrel adapter If the exit opening of the extruder barrel does not match up with the entry opening of the die, an adapter is used between the barrel and die to provide a streamline melt flow. Usually it is placed in the horizontal position. Any adapter used can help reduce complex melt-flow patterns entering the die. Dies specifically designed for a certain extruder will usually not require an adapter. A fish-tail die adapter describes the transition from a round block of melt as it exits from the barrel and is then flattened while being spread prior to entering the die. Also called *offset adapter, cross-head adapter,* or *die feed-block.* See **barrel flange, front.**

extruder barrel and feed unit See **barrel and feed unit.**

extruder barrel borescoping See **barrel borescoping.**

extruder barrel-die coupling The coupling between barrel and die. Various methods include (1) flange fitting with a clamp ring on the barrel and a fixed flange on the die; (2) flanges on the barrel and die with tapered links and two bolted half-clamps, or a ring clamp hinged at one side and bolted to the other side; and (3) swing-bolt flange connection between the barrel flange and a die flange. In most extruders, a breaker plate with screens is used between the barrel and die assembly. See **extruder screen pack.**

extruder barrel downsizing and upsizing See **barrel downsizing and upsizing.**

extruder barrel heat See **heater band.**

extruder-bead sealing See **extruder welding.**

extruder, blow molding See **extruder.**

extruder blown film In this process, the die is usually side fed from an extruder. The melt exiting from a circular or ring orifice is air inflated to the required diameter as it usually moves vertically. The inflated film is then usually cooled through air cooling, with size controlled by the die and cooling ring sizes, by internal air pressure, and by take-off speed. The blown film is usually moving vertically through several guide rolls to keep it aligned with the machine. After a few yards (meters) of free suspension, it is flattened via some type of collapsing device that directs the flattened film through pressure-controlled pull nip rolls. The rotating speed of the nip rolls is a major source for controlling the rate at which the bubble is drawn. At the end of the line, winder technology allows the selection of surface winding, center winding, and a combination of surface and center winding to suit the film being run. Film may be wound directly as a lay flat tube, slit at both sides and wound into two flat reels, slit on one side (so that very wide film can be opened with a visible line due to the fold), and other constructions such as an in-line grocery bag line. Also called *bubble process.* See **calender; die; extruder flat film; fiber fibrillation; film; film, cast; optical monitoring; packaging, food; paint.**

extruder blown film air entrapment Trapped air that forms the continuous tube is directed through a mandrel via the die. Once the bubble has been formed, the controlled air pressure required to keep the bubble stable is kept constant. Usual pressure is 40 ft^3/min (1.1 m^3/min). As the hot tube or melt leaves the die, a cooling system is used that is targeted to uniformly cool the melt. This cooling action has a major influence on the bubble thickness and uniformity. The usual dual- or three-chamber lip-cooling air ring, located outside the bubbles as it exits the die, has air streams gently cooling the bubble. To speed up lines and improve output performances, internal bubble cooling systems are extensively used. They direct cool air at low velocity to enter and exit the inside of the bubble.

extruder-blown film air ring See **extruder-blown film air entrapment; venturi.**

extruder-blown film bag manufacturing As the flat tube passes over a forming mandrel or former, heat sealing or an appropriate adhesive is applied to the edge of the web. The seam is completed by pressure when the joint passes between a set of rollers. As the web continues gussets, with or without zippers, can be added in the tucking-former section. A cut-off converts the web into bags. Bottom heat sealing or adhesive is automatically applied to the trailing edges. Bottom folds and seams are made completing the in-line operation. The most common bags are self-opening styles. See **bag gusset; landfill and degradation; packaging, grocery bag; thermoforming, form, fill, and seal.**

extruder-blown film blocking See **antiblocking agent; blockage.**

extruder blown film blow-up ratio (BUR) A bubble diameter that is normally always much greater than the die diameter. This bubble diameter divided by the die orifice diameter is called the *blow-up ratio*. The BUR is usually 1.5 to 4.0, depending on the plastic being processed and the thickness required. The bubble diameter must not be confused with the width of the flattened double layer of film between the nip rolls. The width of this double layer is 1.57 times the bubble diameter and called the *blown-film width*. The BUR can be determined by taking 0.637 times the lay-flat width divided by the die diameter. Extrusion direction can be horizontal (rarely used). The usual is vertical upward or downward. Choice of direction usually depends on the type plastic or melt behavior of plastic and the desired lay-flat width. Thermoplastics with low melt viscosity are usually blown vertically upward. As a possible guide (since plastic melt-strength performance dictates direction) tube diameters up to about 40 in (100 cm) go downward; tubes greater go upward. See **blow-up ratio; sensor, infrared.**

extruder blown film bubble See **extruder-blown film.**

extruder blown film die See **die.**

extruder blown film die, coextruded These dies can produce at least two to seven layers. They are based on the concept of a die within a die—that is, individual distributing manifolds are used for each layer. Individual plastic melts from their respective extruders are pumped through a feedport system into a die in alternating layers extending radially across the annular orifice opening. Simultaneous motion of the die members, using different motion patterns, includes the inner mandrel rotating and outer ring stationary, the reverse motion, both rotating at the same speed, both counterrotating, rocking motion, oscillating motion, and so on. The deforming action results in long thin spiral layers around the annulus. The total layer thickness is determined by factors such as type plastics, extrusion rate, and the rotational speed of the die mandrel and ring relative to the feedports. Although the layers tend not to be concentric, the difference is indistinguishable when examining the extrudate in cross-section. See **coextrusion; die.**

extruder blown film die, coextruded-reflective Dow Chemical's patent makes multilayer blown film with two different alternating plastics, such as polyethylene and polypropylene—at least 115 layers with a total thickness of 0.5 mil (0.013 mm) thick. Each individual layer's thickness is less than a wavelength of light. The film contains no metal yet offers reflective properties that can mimic chrome plating, aluminum vacuum metallizing, platinum, copper, or others. Depending on construction and degree of differences in their index of refraction, different optical effects are produced. The die is based on the principle of generating a large number of layers by rotation of annular die boundaries. This principle is related to some earlier Dow Chemical work on color mixing of polystyrene. They are also made in flat dies. A tubing die with a rotating type core generates a large number of layers. Two plastics are pumped through a feed-port system extending into a radial pattern across an annular gap. Simultaneous rotation of the die member deforms the two initial layers into long thin spirals around an annulus. Although the layers are concentric, the deformation is usually so large that the spiral characteristic is indistinguishable when examining the extrudate in the cross-section.

extruder blown-film frost line The line at which crystalline melt leaves the die (and moves to a ring-shaped zone where the film approaches its diameter) and changes from a hazy to a transparent (amorphous) condition. This zone is characterized by a frosty appearance to the film caused when the film temperature falls below the softening range of the plastic. The frost line's visual appearance can be a straight or level line or can show a varying line and height that can be related to the processing conditions. Depending on the plastic, unevenness may be acceptable within certain limits. See **packaging, food.**

extruder blown-film gauge distortion Gauge thickness can be extremely nonuniform due to melt behavior on exiting the die or distortions of the collapsing frame. To provide uniformity controlling the melt is required, and different techniques are used to handle the film, such as rotating dies or oscillating film haul-offs. Different systems are available to meet different requirements, such as web width, cooling system effect, degree of tack or film stiffness, line speed, or gauge thickness. See **thickness gauge.**

extruder blown film gauge randomization One solution to the randomization problem is the rotating or oscillating die system, which is rather low cost and mechanically simple. In most cases, the air ring is mounted on the die so that the inner part of the ring rotates with the die. Meanwhile, the inlet chamber remains stationary. In the past, the majority of the dies had a full 360° rotation. Most of these type systems now have dies oscillating. Unfortunately, these systems only randomize the mechanical and melt variables caused from the die to the air ring. They do not address the gauge bands caused by external effects such as air-ring irregularities (lip irregularities, variable air flow and temperature, etc.), ambient drafts, bubble alignment forces (cages, guides, collapsing frame, etc.), tower, drafts, melt channeling, or other factors above the air ring.

extruder blown film gauge randomization, oscillating A modifications of the basic randomization system. For example, an extruder and die can be mounted on a platform, which oscillates in a complete circle. The oscillating haul-off systems provide the best way to randomize film-gauge variation for many applications. Imperfections in circular dies and air rings with process variables cause variations to develop. There are basically two types, and in turn each has many variations. One has horizontal mounted turning bars that use less head room but have a more complex threading operation. The other type is the vertically mounted turning bars that are simple to thread and easy to maintain alignment.

extruder blown film gusset A tuck that is taken on each side of a blown tubing as it is produced to form a convenient square or rectangular package, similar to the familiar brown paper bag.

extruder blown film internal bubble cooler (IBC) A device that provides additional cooling advantages for the film traveling from the die to the nip rolls, further improving total cooling with the air ring. See **nitrogen gas and liquid.**

extruder-blown film lay-flat Film produced at the end of an extruded blown film tube line where it is laying flat around the wind-up roll.

extruder-blown film nip roll See **extruder-blown film; extruder roll.**

extruder-blown film or flat film See **extruder flat or blown film.**

extruder blown film orientation The blown tubular film process, by its nature, gives orientation to the plastic. Systems have been designed to increase the degree of orientation to obtain films of improved clarity, strength, heat resistance, and so on. Except for special applications, where greater strength in one direction may be needed, films are normally made with balanced properties. During processing the blow-up ratio determines the degree of circumferential orientation, and the pull rate of the bubble by the nip rolls determines longitudinal orientation. As an example, the optimum stretching for amorphous plastics (PVC, etc.) is just above the glass transition temperature; for crystalline plastics (PE, PET, etc.) it is just below the melting point.

During the stretching process, the structure changes because of crystallization, usually necessitating an increase in heat if further deformation is planned. Afterward, the orientation is "frozen in" by lowering the heat or, with crystalline types, set by increasing the crystalline portion. With orientation, the thickness is reduced, and the surface area enlarged. If film is only longitudinally stretched in the elastic state, the thickness and the width are reduced in the same ratio. If lateral contraction is prevented, stretching reduces the thickness only. See **orientation.**

extruder blown film plastic Plastic materials can account for 70 to 90% of film production cost. Reducing excess plastic and producing quality products have always been the goal of processors. This goal can be obtained by meeting minimum tolerances, operating the extruder most efficiently, and using new technology that reduces scrap such as during start-up and shut-down. For example, a manually operated modern film line can produce a film with a high degree of homogeneity and finish. The thickness, however, might fluctuate up to 5% due to changes in material bulk density. With on-line weight-measurement systems that continuously measure material consumption through the hopper to the plasticator, thickness changes can be significantly reduced. Gravimetric measurement systems are available that can provide measurement accuracy to ±0.25%.

extruder blown film scrap In the extrusion process the major sources of scrap are (1) edge trim, which is usually granulated and recycled with virgin plastic at the machine; (2) thickness variation not meeting the tolerance requirements that is usually a minimum; and (3) production start-ups, shut-downs, and changeovers. If a converter has to use gauge-variation materials, the customer usually has a major inefficiency. If it can be used so that the converter can meet delivery schedules, during the conversion the film has to run much slower in the presses, laminators, bag machines, and so on. With changeovers, film-extrusion lines can produce scrap at the rate of up to 500 to 1000 lb/h (227 to 454 kg/h). By the time operators set up proper controls for the production line, which could take up to two hours, scrap is accumulating. Costs go up for the recycling action, and the line has to be carefully controlled if more than the usual amount of scrap is blended with virgin plastics. See **recycling.**

extruder blown film tension control See **extruder-web tension control, slipping and tearing; extruder-web stretching and tearing.**

extruder blown film tower See **tower.**

extruder blown film wavering See **resonance, draw.**

extruder borescoping See **barrel borescoping.**

extruder breaker plate See **extruder screen pack.**

extruder bridging See **screw and barrel bridging.**

extruder capping See **coextrusion capping.**

extruder capstan See **extruder wire and cable capstan.**

extruder cast film See **extruder flat film.**

extruder choke plate A single-hole unit that is used between the end of an extruder barrel and the die holder to produce a controlled pressure drop in the plastic melt flowing through the die.

extruder cleaning See **cleaning.**

extruder, co- See **coextrusion; coextrusion foam core.**

extruder coating and lamination The basic units of an extrusion coating line consist of the unwind station, extruder, coating or laminating unit, and windup unit. When coating, a plastic material is applied to the surface of a substrate. Laminating combines two or more substrates together by bonding them with a material such as plastic. The basic common principle involved in coating and laminating is that a very hot plastic melt is used. The main purpose for either technique is to combine the best properties of the plastics and substrates. Over 100 different processes are used just to coat materials, but very popular for long runs is the extruder. These dedicated fast lines are used since they provide quality-controlled products and are very cost efficient. The process itself tends to be complex since it contains many controllable variables, where each variable as well as its interrelation with others affects the quality of the coated or laminated product. In general, the processing temperature used in extrusion coating is higher than that used in the other extrusion processes.

Melt temperatures for the conventional plastics are normally 550° to 575°F (288° to 300°C). The higher temperatures are required to affect adhesion to the substrate. This higher temperature puts the plastics closer to being degraded. See **coextrusion; extruder neck-in and beading; extruder profile coated; fabricating process; laminate; resonance, draw; roll.**

extruder coating and lamination air gap The vertical distance from the opening of the die to the nip formed by the pressure roll and chill roll.

extruder coating and lamination curtain The curtain identifies the hot melt leaving the die orifice.

extruder coating and lamination process The extruder is located on some type of guide rails or rolls so that it can be retracted from over the coating or laminating line. On start up the extruder is operated to develop the ideal melt. Once the melt is acceptable, the extruder is moved forward on the rails and over the line to start applying melt to the substrate. When the line is to be shut down, the extruder is retracted and also shut down. The melt from the extruder forces melted thermoplastic material through a horizontal slit die onto a moving web or substrate. The rate of application is controlled by the amount of extrudate leaving the die and the pull rate that occurs as soon as the melt is pinched by a set of rolls. The melt stream could be a coextruded layer. As the melt leaves the die lips, the thin melt film is pulled down into the nip between two rolls located directly below the die. The substrate, which is traveling at a speed faster than the extruded film, draws the hot film. The combination of these two different speeds, with the pressure applied between the two rolls, relates to the required thickness to be applied to the substrate. The two rolls are the chill roll and the pressure roll that forces the film onto the substrate. See **coating; doctor roll; roll.**

extruder coating, curtain See **coating, curtain.**

extruder coating roll See **extruder roll coating, kiss.**

extruder, coextrusion See **extruder-blown film die, coextruded; coextrusion.**

extruder cold shot Starting up an extruder requires that temperature equilibrium be achieved sufficient to melt the plastic at a rapid enough rate to form an appropriate extrudate. Before this is achieved during start-up, several incomplete extrudates (cold shots) will be formed while cycling the machine. See **molding cold slug.**

extruder color changeover As a guide with or without gear pumps, when changing plastics or colors, first bring the melt temperature up 50°F above normal processing levels. Introduce a clear PE or PP plastic of 1.0 to 2.0 MI, and purge for a few minutes. Then add a few pounds of commercially available chemical purging agent. Finally, introduce a few minutes more of the clear plastic, and follow with the new plastic, adjusting the melt temperature to the appropriate levels. See **colorant.**

extruder communication protocol See **communication protocol.**

extruder compacting The compacting of a plastic and the forcing of it through an orifice in more or less continuous fashion. See **compacting.**

extruder compound mixing Large-scale compounding that is done on either single- or multiscrew extruders. Single screws are used for basic operations where little variation in material formulation and viscosity is expected. Most compounding is done in multiscrew (twin-screw, etc.) compounders since they offer better conveyance characteristics and production rates. See **compounding; extruder, twin-screw; mixer; plastic material.**

extruder, computer-integrated See **computer-integrated manufacturing.**

extruder, concentric-screw mixer A variation of the single-screw compounding extruder design. An example is a screw or rotor that has changing diameters over its entire length and rotates inside a series of concentric stator rings fixed to the barrel. Stator and rotor grooves are opposite-handed, and they alternatively increase and decrease in depth. See **mixer; screw.**

extruder, continuous-molding See **blow molding, extruder (continuous); injection molding, continuous; Velcro strip.**

extruder controller See **control actuator; die head, programmed; microprocessor control; process control.**

extruder cooling and takeoff equipment As the "fluid" plastic melt leaves the die, it usually has to be supported by a shaping fixture or sizing fixture. It retains a desired shape through the period when the plastic cools. For rod and tubing, a metal cooling device (steel or brass sleeves, flat sizing plates, etc.) can be used. Cooling is provided by a water trough or tank or a water cascade, except for those rigid plastics that can be cooled in air. With certain plastics, water cooling sets up internal stresses and gives a poor surface appearance. Other techniques are used to speed up the line, such as cryogenic or nitrogen liquid cooling. It is common practice to pipe the extruder's water supply for the plasticator feed section and gear box in parallel with numerous other devices like cooling rolls or even other extruders. If one of the flow paths has a low resistance to water flow, most of the cooling water will take that path and unbalanced cooling operation will exist. In these cases, it is necessary to add a booster pump in the supply line to the extruder. See **coolant; die, dry-sleeve calibration.**

extruder die See **die; extruder, multiple-die.**

extruder die pressure See **die pressure.**

extruder dispersion aid See **extruder screen pack.**

extruder doser See **doser.**

extruder downtime See **processing line, downtime; processing line, uptime.**

extruder draw-down The process of pulling the extrudate away from the die at a linear speed higher than that at which the melt exits the die, thus reducing the cross-section dimensions of the extrudate. See **die draw-down ratio; extruder wire and cable die draw-down.**

extruder drive The entire electrical and mechanical system that is used to supply mechanical energy to the input shaft of the gear reducer. This includes electric or mechanical motor, constant or infinitely variable speed system and flexible coupling. See **design, motion-control, mechanical and electronic effects; drive motor control; electric motor.**

extruder drive backlash The working difference or clearance between tooth space and tooth width as measured on the pitch circle. This allows the gears to mesh without jamming. See **backlash.**

extruder drive-energy consumption Like the output capacity, the energy efficiency of an extruder is dependent on the torque available on the screw, screw rpm, heat control, and material being processed. Note that a high torque extruder would result in very inefficient processing (cost) when only a low torque extruder is required. See **drive-system control; electric motor; electric motor, adjustable-speed-drive; electric motor drive; energy input, machine; energy loss, machine.**

extruder drive maintenance An example of maintenance involves possibly twice a shift checking ampere, voltmeter, and screw rpm instruments. A sudden increase or decrease in motor load means trouble, with screw temperature being a prime suspect. Rpm gauge fluctuation, however slight, justifies a call to a drive-service person if the cause is not immediately found.

extruder, dual-plastic Extruding a shape with two plastics simultaneously. A transparent strip can be extruded along with the rest of a nontransparent material, a profile with a soft and hard material, and other combinations. See **maintenance.**

extruder drool See **die drip.**

extruder, elastic melt One extruder has twin rotating discs that use plastic melt elasticity in effect to convey the melt. Another has material fed into a fixed gap between a stationary and a rotating plate. Frictional heat develops the melt condition that is discharged through a die. Only plastics with certain elastic properties are suitable for this process. Also called *elastodynamic extruder.*

extruder energy saver See **electric motor, adjustable-speed-drive; energy loss, machine.**

extruder extrudate See **extrudate.**

extruder feedback-control system A method of controlling extruder output by adjustment of speed or back pressure to maintain a constant output rate.

extruder, fiber See **fiber processing.**

extruder, fiber solid state See **fiber processing, solid-state extrusion.**

extruder filament See **fiber processing; filament.**

extruder film See **calender; cast; extruder-blown film; extruder flat film.**

extruder-film arrowhead The shape formed when lines meet at a rounded angle. They point in the direction of extrusion.

extruder-film blocking See **film blocking.**

extruder-film brittleness The tendency, such as with bags, to split along a fold, crease, or gusset as well as across a film when rapidly stressed. This characteristic depends mainly on plastic density and molecular properties such as orientation, MI, MWD, and so on. Lower density is less brittle. See **brittleness; molecular weight distribution; orientation.**

extruder-film capping See **coextrusion capping.**

extruder-film cast See **film, cast.**

extruder-film control See **extruder-web stretching and tearing.**

extruder-film cooling, roll versus quench-tank In chill-roll or cast-film extrusion, the melt extruded through a die slot is cooled by the surface of two or more water-cooled chill or casting rolls. This offers substantial improvements in optical properties, transparency with freedom from haze and gloss, potential increase in output, and production of stiffer films. A major problem that could be encountered in cast film is puckering. They are film nonuniformities that usually develop on the first chill roll. They look like small pockets or bags.

extruder film, reflective See **extruder-blown film die, coextruded-reflective.**

extruder-film static charge See **film, electrostatic charge.**

extruder-film thickness See **die, film and sheet thickness for a; optical monitoring.**

extruder flat film A process that is similar to flat film processing and the casting processes to produce film (and sheet) from highly fluid solutions. The most popular process used to produce the flat film is with chill rolls. The process that uses a water-chill tank or quench film is also popular. See **film, cast.**

The flat-film chill-roll process usually has low melt viscosity plastic extruded through a coat hanger or T-shape slot die that may be at least 10 ft (3 m) wide. The extrudate is chilled below the melt temperature (T_m) or glass transition temperature (T_g) by passing it principally over two or more chrome-plated chill rollers (that have been cored for water cooling), or a water-bath system may be used. The extrudate web from the die is made dimensionally stable by contacting several chill rolls prior to being pulled by the nip or pull rolls and wrapped around the wind-up roll. See **extruder roll cooling; glass transition temperature; melt temperature; packaging, food.**

The rapid-water-quenching system produces good optical properties, has low equipment cost, but can be difficult to use to get precise control over the water temperature. Vibrations and currents can cause little marks on the film. A critical point is the necessity for maintaining a smooth surface in the water quench tank where the melt first enters. Different devices are used to control the flow of water such as baffles with openings. It has serious limitations when high production speeds are attempted; the water must be kept from carrying over into any on-line pretreatment and the finished roll. However, these problems can be controlled. This liquid bath system has been used for blown tubular film inside the blown film to improve cooling characteristics. Also called *chill roll film, roll cast film, cast film, slot cast film,* and *water-chill film.*

extruder flat-film antiblocking See **antiblocking agent; sheet blocking.**

extruder flat-film chill roll See **extruder roll cooling.**

extruder flat-film draw-ratio (DR) Film around a chill roll or water bath at continuously increasing rates of output can begin to pulsate rhymically at a critical draw ratio. DR is the melt's final velocity to its velocity in the die. As the DR increases, the pulsation's become more pronounced. This phenomenon is known as the *draw resonance.* It can occur in any melt-drawing process such as coating, spinning, and melt embossing as long as the extrudate passes through the two fixed points of a die and a fixed velocity take-off point. For certain plastics the draw resonance (DR) occurs under a DR of 20 for film. In coatings and embossing the ratio is about 30. The method used to eliminate draw resonance is a *draw resonance eliminator* (DRE). It directs a fluid medium (air knife) against the melt between the die and chill roll. See **extruder sheet air knife; fiber processing; resonance, draw.**

extruder flat-film neck-in See **extruder neck-in and beading.**

extruder flat-film orientation In flat-film extrusion, particularly at high take-off rates, there is a relatively high orientation of the film in the machine direction (MD) of the extrudate flow and a very low orientation in the transverse direction (TD). However, the film can be made to be bidirectional (BD). The effects of biaxial orientation are important in film manufacture such as PP, PE, PET, and PVDC. Stronger films of high clarity result. The orientation-induced crystallization of the plastics produces molecular structures that do not interfere with light waves. For example, when biaxially stretching PS using a 4:1 ratio in both directions, the higher tensile strength of 10 to 12 ksi (70 to 80 MPa) is achieved compared to 6 to 8 ksi (40 to 55 MPa) for unstretched PS film. See **orientation, tenter frame and roll.**

extruder flat-film tape Tape (narrow film) for sound and video recording, packaging strapping, and so on is usually made from PP or PETP plastics, which are highly oriented in the machine direction. The initial tape, which may be up to 1½ by 0.06 in. (40 by 1.5 mm), is usually made by vertical extrusion into a water bath with a limited draw-down. Water temperature is kept low, and the distance of the surface from the die is as small as 0.2 in. (5 mm) to give rapid cooling and low crystallinity. The tape is then reheated to a temperature well below the crystalline melting point and drawn lengthwise by 10:1 or greater, producing a high degree of uniaxial orientation. It is then heat set by heating to a somewhat higher temperature while held under tension to crystallize in the oriented state and then cooled. The low initial crystallinity provides high elongation to break. See **extruder-web tension control.**

extruder flat-film tension control See **extruder-web tension control, slipping and tearing; extruder-web stretching and tearing.**

extruder flat-film thickness See **optical monitoring.**

extruder flat-film wavering See **resonance, draw.**

extruder flat or blown film In certain respects chill-roll flat-film production is similar to that of blown film, though thickness variations due to mechanical distortion of the die assume greater importance. A die deflection represents a greater percentage on a thinner film, and the increased die resistance leads to higher melt pressures. Higher velocities are also required to give similar outputs. This problem is usually resolved by using high draw-down ratios of 10:1 or more on thickness using wider die gaps of about 0.02 in. (0.5 mm). The result is lower die velocity and pressure and improved percentage of thickness tolerance. The thinner films are also more flexible, so the unsupported gap between die lips and haul-off or cooling roll must also be reduced.

Whether one uses flat or blown film depends on the applications, performance requirements (transparency, etc.), length of production run, and cost. The main advantage of flat film is the intensive cooling accomplished by means of chill rolls or water. There are few difficulties in the melt, and blocking rarely occurs. Another advantage is that there is no flattening operation; the problem of maintaining a constant bubble volume does not exist. Control of thickness across the width of the film is simpler. The winding and printing of the flat film are usually simpler. It provides better gauge uniformity, better embossing quality, higher rates of production per total web width, lower density, and softer film. See **extruder cooling and takeoff equipment.**

extruder flat- or blown-film capability The blown-film capabilities of equipment and materials can cause many of the flat-film advantages to be less significant. Blown film can process those plastics that go through flat-film lines and in addition those plastics with other melt characteristics. The blown film does not require edge trimming or requires less regrind, has better balance of mechanical properties, denser film, stiffer, and improved barrier properties.

An advantage of blown-film extrusion over flat film is the ability to produce film with a more uniform strength in both the machine direction (MD) and transverse direction (TD). In flat-film extrusion, particularly at high take-off rates and not using tenter orientation equipment, there is a relatively high orientation of the film in the MD and a very low orientation in the TD. In blown film, by balancing blow-up ratios against take-off rate, it is possible to achieve physical and other properties that are very nearly equal in both directions, such as giving a film maximum toughness.

Another advantage of blown film (with a tight tolerance on thickness) can be in bag production. It requires, with the proper-size blown tube, one seal across the bottom of the bag, whereas with flat film either one or two longitudinal seals are necessary. Blown diameter can be produced, giving flat film widths that are much wider than anything produced by flat slot-die extrusion. In addition to packaging, large-width PE film have been used extensively in other markets, such as the building, agriculture, and horticulture industries. In certain secondary operations a tight thickness tolerance is desired to ensure proper performance, minimize the amount of plastic consumed, and reduce cost.

extruder, foam There are the tandem foam extrusion line (which is predominantly used) and the single extrusion line. The tandem uses two single-screw extruders. The startup or the primary extruder melts the plastic, mixes in the blowing agent (usually nitrogen at about 1,000 psi (7 MPa)) with additives, and feeds the extrudate to the second extruder under pressure. This second phase cools the extrudate to the proper uniform melt temperature, thus providing a better stable melt into an annular die, where it expands into the foam sheet. A check valve can be used to control back flow of the blowing agent. A foamed-tube die opening delivers the expanded controlled thickness foam over a dome-shaped cooling and shaping form. This tube can be slit into two halves. The result is that two flat, foamed sheets go downstream to windup rolls. See **foam.**

extruder forming See **extruder postforming; postforming.**

extruder, free An extrusion line that takes the extrudate and uses no special downstream equipment. It cools the extrudate using air, water, or a combination of both. No special forming device, controlling fixture, sizing device, and so on is used.

extruder freeze line See **extruder-blown film frost line.**

extruder freeze-off See **freeze-off.**

extruder gear box Because extruder motors deliver approximately constant torque over their speed range, the power available increases linearly with speed. For maximum power, therefore, the motor should be run near its top speed. To match optimum motor speed with maximum screw speed, a gear box with a reduction ratio between 10 : 1 and 20 : 1 is usually used. The power-transmission capability of the gear box is matched to the maximum motor power. A belt drive with some speed reduction can also be incorporated into the drive transmission. This provides some safety against sudden overloads where power losses can be as high as 10%. With proper maintenance, gearboxes should last at least 20 years. Also called *gear case.* See **backlash; fabricating output.**

extruder gear pump See **gear pump.**

extruder gel If the extruder die is producing gels due to plastic degradation or die lip buildup, using 200 to 600 ppm of fluoropolymer processing aid in combination with antioxidant additives can reduce these type of problems. See **gel.**

extruder, glass-fiber See **fiberglass production.**

extruder godet unit A multiple roll drive that is usually used on monofilaments and strips where the extrudate is driven by the friction between the extrudate and the rolls. It is used to orient monofilament. See **filament, mono-.**

extruder gravimetric feeding and blending See **feeder, gravity.**

extruder grooved feed See **barrel grooved feed.**

extruder haul-off A system that pulls the extrudate away from the die; usually a series of rolls or caterpillar equipment.

extruder head angle An extruder head, such as in wire coating, that is positioned at an angle (45°, 90°, etc.) with the axis of the screw and does not have the head in the usual position of being in line with the screw.

extruder heat-transfer mechanism See **heat-transfer mechanism.**

extruder, house wall See **plastic house.**

extruder improvements Although the single-screw extruder is one of the oldest types of machinery for plastics processing, it has not yet reached the end of its development because of changes in plastic materials, processing requirements, machine operation, and market requirements. Rheological data that are based on plastic performances during processing have helped advance the art of extruding plastics. See **market.**

extruder-injection molding process See **Velcro strip.**

extruder inspection See **screw inspection.**

extruder instability or variability In extrusion, as well as other processes, extensive theoretical analysis are applied to facilitate understanding and maximizing the manufacturing operation. However, the "real world" must be understood and appreciated as well. The operation has to work within many limitations of the plastics, additives, and primary and secondary equipment. The interplay of process controls can help eliminate or decrease variations. Most instabilities are caused by improper screw design or wrong screws. Proper instrumentation settings, particularly barrel heat, are important to diagnosis. For uniform or stable extrusion, it is important to check the drive system, the take-up device, and other equipment periodically, and compare the readings to their original settings. An elaborate process-control system can help, but it is best to improve stability in all facets of the extrusion line. Examples of instabilities and problem areas are (1) nonuniform plastics that flow into the hopper, (2) troublesome bridging that varies or stops plastic flow due to excessive barrel heat that melts and solidifies plastic in the hopper and the feed section of the screw, (3) variations in barrel heat, screw heat, screw speed, screw power drive, die heat, die-head pressure, and take-up devices, (4) insufficient melting or mixing capacity, (5) insufficient pressure-generating capacity, (6) wear or damage of the screw or barrel, and (7) melt fracture or sharkskin. The extruder and the downstream equipment must be properly aligned. Proper alignment and isolation of the vibrators is a must for high-quality, high-speed output. To support the alignment, proper instrumentation is vitally important for quick and accurate diagnosis. A prerequisite for stable extrusion is a good extruder drive, a good temperature-control system, an accurately controlled take-up device, and—most important—a good screw design. The extruder should be equipped with some type of proportioning temperature control. See **process control.**

extruder, intermittent molding See **blow molding, extruder (intermittent); extruder; injection molding.**

extruder IR temperature controller See **injection-molding infrared temperature controller; spectroscopy, Fourier's transfer infrared.**

extruder, isothermal A process where the melt stock remains at constant temperature for a good portion of time in the plasticator. This type of operation is most common in small-diameter screw extruders. See **isothermal.**

extruder kneader/mixer See **mixer, kneader extruder.**

extruder lamination See **extruder coating and lamination.**

extruder length-to-diameter See **screw length-to-diameter ratio.**

extruder line The extruder and its components (gear pump, die, etc.) are costly. However, the other equipment in the line (train) is usually more expensive. Major costs may be incurred at the end of the extrusion line, such as in finishing, trimming, postforming, and the windup or stacking equipment. For example, up to one-third of the capital-equipment cost in a film line can be for the winder. Sophisticated materials-handling equipment becomes costly.

extruder liquid-curing-medium (LCM) process A continuous curing method that is well suited for extruded elastomeric goods, such as neoprene (solid or sponge). Uncured stock passes directly from the extruder into a liquid heat-transfer medium maintained at a temperature of about 200 to 250°C (392 to 482°F). Molten metals (such as an eutectic mixture of 58wt% bismuth and 42% tin), heat-stable organic liquid (such as polyalkyline glycol), and molten salt (eutectic mixture) are used to provide rapid heat transfer. Curing times of 90 s or less are possible with cross-sections up to 9.5 mm (0.4 in.) thick. Vulcanizates of neoprene cured at these extremely high temperatures have properties fully equivalent to vulcanizates cured for longer times at lower temperatures. See **eutectic mixture; fluid-bed process.**

extruder lockout See **safety, machine-lockout.**

extruder log See **reinforced-plastic bulk-molding compound.**

extruder machine alignment See **machine alignment.**

extruder machine control See **controlled motion; drive-system control; process control; repeatability; servo-control-drive reliability.**

extruder machine energy See **electric motor, adjustable-speed-drive; energy input, machine; energy loss, machine.**

extruder machine fabricator process simulator See **process simulator.**

extruder machine L/D ratio See **screw length-to-diameter ratio.**

extruder machine maintenance See **maintenance.**

extruder machine safety See **safety.**

extruder maintenance Maintenance and preventive maintenance procedures decrease or eliminate downtime and optimize performance. The machine operator or the maintenance personnel can follow the guides from extruder manufacturers that explain maintenance procedures. A firm schedule for maintenance should be established. As a safety practice, the extruder must be properly shut down when any maintenance (or inspection) is performed that can cause injury. See **maintenance, preventive; inspection; processing-line downtime.**

extruder marbleizing See **screw marbleizing.**

extruder market See **market; plastic consumption.**

extruder material consumption See **plastic consumption.**

extruder material handling See **material handling.**

extruder-melt bambooing A manifestation of melt fracture in which the extrudate consists of smooth sections interrupted by a periodic distortion on the surface that has the appearance of bamboo. See **melt fracture.**

extruder melt blockage An interruption of melt flow that occurs with rapid drop in output and motor amps. It may have various causes: (1) a screw may stick in the barrel when the line is stopped with the screw full of plastic so that oxygen can therefore be kept from getting down to the hot breaker plate, promoting degradation and contamination (the remedy includes having the screw rotate at a very slow speed, using an internal cooled screw for certain plastics such as plasticized PVC, or emptying the screw); (2) an obstruction or melt may stick in the feed passage (the remedy includes reducing heat build-up); and (3) the screw compression zone may surge due to insufficient soft melt to be properly compressed (remedy includes raising the rear barrel temperature). See **blockage; screw.**

extruder melt flow See **melt flow; melt-flow defect; test, melt-index.**

extruder melt-flow instability See **melt fracture.**

extruder melt-flow orientation See **extruder-blown film orientation; orientation, accidental.**

extruder melt-flow oscillation The extruder or melt gear pump can have some flow oscillation so that the amount that reaches the product is less than the amount that leaves the die. The amount of dampening of the oscillations will depend on the delivery-system characteristics, such as the geometry and condition of the gear pump. Pumps with few large teeth have a greater amplitude than do similar pumps with more smaller teeth for the same flow rate. The frequency is typically a function of extruder or pump speed. Therefore, a higher-speed machine will have a greater dampening of its flow oscillations than will a slower machine. The compressibility of the plastic is normally fixed, but the elasticity of the delivery system can be increased to alleviate flow surging. Factors such as greater die pressure and the presence of pressure drops (such as a filter) lower the surges. See **injection-molding melt-flow oscillation; melt-flow oscillation; weld line.**

extruder melt-pressure transducer See **transducer, pressure.**

extruder melt-temperature effectiveness See **melt-temperature effectiveness.**

extruder melt-temperature sensitivity See **temperature sensitivity.**

extruder melt tracer See **tracer.**

extruder melt vibration See **melt vibration.**

extruder mixer See **mixer, extruder.**

extruder motor and gear reducer See **extruder drive.**

extruder, multiple-die Using two or more dies at the end of an extruder may not be desirable but has certain benefits. It may be more economical to use one extruder to deliver to two dies than have a separate extruder for each die. Normally, setting up one extruder with the usual one die can cause problems if it does not operate at maximum efficiency. However, delivery schedules may require the use of two or more dies.

extruder, multiple-screw The main characteristics of these mixing machines include (1) their high conveying capacity at low speed, (2) a positive and controlled pumping rate over a wide range of temperatures and coefficients of friction, (3) low frictional (if any) heat generation, which permits low heat operation, (4) low contact time in the extruder, (5) relatively low motor-power requirements and self-cleaning action with a high degree of mixing, and (6) positive pumping ability that is independent of the friction of the plastic against the screw and barrel and that is not reduced by back flow. Similar to the single-screw extruder, the multiscrew, including the more popularly used twin-screw extruder has advantages and disadvantages. There are corotating and counterrotating screw systems. The cylindrical screws (parallel twin-screws) dominate the market for counterrotating twin-screws, and the extruder fitted with conical screws. The type of design to be used will depend on performance requirements for a specific material to produce a specific product. See **barrel length-to-diameter ratio; compounding; extruder reactive versatility; extruder, single-screw; screw.**

extruder, multiple-screw operation With the multiscrews, very exact metered feeding is necessary for certain materials, otherwise output performance will vary. With overfeeding there is a possibility of overloading the drive or bearings of the machine, particularly with counterrotating screw designs. The intensive mixing action of multiscrew extruders is highlighted by the fact that adjacent layers of plastic have different speeds—namely, velocity gradients or shear rates. In addition to the actual mixing effect, due to displacement of layers with respect to each other, pigment particles or ungelled particles of the plastic (fish eyes) are broken down by its limited friction action, especially in highly viscous plastics. See **extruder, multiple-screw; extruder, twin-screw.**

extruder, multiscrew See **extruder, multiple-screw.**

extruder neck-in and beading With coating as well as other flat-film and sheet processes, on exiting the die the hot film will shrink across the width. The relatively high degree of draw-down over a short distance requires high elongation with generally high melt temperatures. As many films are manufactured from crystalline (semicrystalline) plastics, the rapid cooling tends to suppress crystallization. This molecular action is beneficial in providing high elongation of the cooled film for subsequent drawing or orientation processes. This shrinkage or neck-in is the amount of shrinkage from the die face to the downstream width. With neck-in there is also beading, which is the thickening at both edges of the film. The neck-in and beading influence the performance of the coating as well as the film or sheet, such as wrinkling, sagging, and induced unwanted stresses. Material capability and particularly processing conditions influence these undesirable effects. Later in the line, these beads are trimmed. Certain die designs practically eliminate edge bead.

extruder netting Extrusion dies can be designed to produce different flow patterns, such as tubular to flat netting types. For a circular output, a counterrotating mandrel and orifice can have semicircular shaped slits through which the melt flow emerges. The slits can be of any shape. If one part of the die is held stationary, then a rhomboid or elongated pattern is formed. If both parts of the die rotate, then a true rhombic mesh is formed. During the time when the melt extrudes through the orifice and the slits overlap, a crossing point is formed where the emerging threads appear to be welded but are merely a uniform melt flow through the matching or aligned slits. For flat netting, the slide is in opposite directions. See **extruder postforming.**

extruder operation optimization See **injection molding operation optimization.**

extruder operation shutdown The extruder is commonly run to an empty condition when it is being shut down. This action ensures that there is no starting up with cold plastic, a condition that could overload the extruder if improper start up occurred. Some extruders, such as those processing polyethylene film, are shut down with the screw full of plastic. This prevents air from entering and oxidizing the plastic. Because polyvinyl chloride decomposes with heat, to ensure that this material is completely removed at shut down, purging material such as low-melt PE that can remain in the barrel is used. On start up, it is preferable to raise the barrel heat slightly above its normal operating temperatures so that the higher temperature will ensure that unmelted plastic will not produce excessive torque in the screw. With the downstream equipment, such as with film or sheet lines, some threading should be left for an easy startup as reviewed in startup. See **extruder operation startup; fabricating startup and shutdown; plastic processing.**

extruder operation startup When starting up a new extrusion setup, start the screw rotation at about 5 rpm. Gradually look into the air gap between the feed throat and throat housing, and make sure the screw is turning. Screws may have been installed without having their key in place, or the key may have fallen out during installation. Antiseize material must be applied to the drive hub to help installation and removal. If the key is left out, the drive quill is turning, and the screw is not, the screw will not gall to the drive quill. The procedures of starting a processing line through the downstream equipment, such as sheet or film, can be by "threading" (with a thread, rope, tape, or other material form) a material as it goes through the various downstream units. As in an extruder line, the extrudate is attached to the thread-up end, and in turn the thread-up is pulled through the line carefully and safely. See **extruder operation shutdown; fabricating startup and shutdown; plastic processing.**

extruder operator's sequence See **operation, automatic; operation, manual; operation, semiautomatic.**

extruder, optical fiber See **fiber optic; extruder wire coating, optical-fiber.**

extruder output rate A rate that is usually expressed in lb/h or kg/h.

extruder output recovery rate The volume of melt that is discharged from the screw per unit time in $in.^3/s$ (cm^3/s) when the screw runs on an on-off cycle.

extruder output variation The variation of melt flow that can be estimated by measuring the pressure variations.

extruder particleboard See **particleboard.**

extruder part shrinkage See **blow molding shrinkage; design shrinkage; molding shrinkage; shrinkage; tolerance and shrinkage.**

extruder part shrink fixture See **shrinkage block jig.**

extruder paste The "paste extrusion" process is unique to certain plastics such as PTFE plastics. The plastic is blended with 15 to 20wt% of a lubricant that may be any one of many organic liquids, such as naphtha, odorless kerosene, or white oil. It is readily compressed and extruded to form thin insulation on wire, thin-walled tubing, ribbon, and other shapes. These operations are usually carried out at temperatures between room temperature and 100°C (212°F). The procedures are discontinuous, with the extrudate going from the extruder through a drying operation for removal of the lubricant and then through a sintering operation. Interruption occurs when a new charge of lubricated powder that is usually preformed enters into the plasticator. See **paste; mixer, double-arm.**

extruder pipe and tubing Plastic pipes and tubings have different definitions that are usually associated with different industries (plumbing, gas transmission lines, beverages, medical, mining, and so on). A popular definition for pipes is that they are rigid, hollow, long, and larger in diameter than tubes. Tubings are basically the same except flexible and smaller in diameter such as up to 0.5 in. (0.13 mm) or with thin walls up to 6 in. (15 cm). Practically all pipe is extruded using thermoplastics. Single-screw extruders are usually used, but with PVC, twin-screw extruders are also used. Dies in some of the lines use the same basic dies and plastic melt temperature ranges that are used in wire coating.

The basic in-line process (or train) for the production of pipe starts with material handling upstream from the extruder. The extruder and die as well as devices for the outside and inside calibration of the pipes cross-sectional area, if required, use air or nitrogen pressure or vacuum to contain the pipe shape. Wall thickness measuring device, cooling tank, and automatic cutting with pallet equipment for rigid pipe or windup unit for flexible pipe are downstream. The line could include a marking device, testing device, and so on. An important requirement is to cool the extrudate rather fast near the die while keeping control of dimensions and properties. See **coolant; design, corrugated; extruded wire and cable die; orientation and heat-shrinkability; pipe, geothermal; pipe market; pipe, water deterioration of; tubing; tubing, microbore.**

extruder pipe and tubing approach Various techniques control the dimensions and sizes, and these are either free-drawn melts (usually for the small-diameter tubes) or sizing fixtures. Because producing the pipe includes a material cost of up to 80%, the goal is always tighter tolerance control to reduce material consumption. Dimensional or thickness-calibrating disks of different designs are used. Small-diameter tube lines use draw-down control (free-extrusion) sizing technology where the extruded tubular melt has no calibrating device after leaving the die. Internal air pressure prevents the tube from collapsing on leaving the die. Some devices also have different calibrating and sizing plates or tubes, with or without pressure, and with vacuum assist in or outside the tube.

Sizing during cooling is almost universally controlled either on the outside diameter (OD) or inside diameter (ID). This approach uses the minimum amount of plastic. The dimensions of the die and the relation between its output and haul-off rate determine the final wall thickness and consequently the OD and ID. In some applications the ID has to be precise, such as in producing disposable hypodermics and beer pumps. Precision OD is required for applications such as the pipe fit into a pressure tank. See **cut, fly.**

extruder pipe and tubing die Most of the pipes and tubes are processed with in-line straight-through extruder dies. Crosshead extrusion dies include those without spiders that split the melt on the opposite side of the extruder. A crosshead die is used when the processor also extrudes wire coatings and when spiders in a die must be eliminated. See **die.**

The die system has the following important features: (1) the extruder adapter and die are designed to target for a smooth streamline melt flow; (2) the mandrel's supporting spiders or webs should have a smooth symmetrical (airfoil/streamline shape) profile beginning and ending with near knife edges; (3) the holdup area of the spiders should be minimized; (4) the cross-sectional area between the supporting spiders of the mandrel should be at least three times greater than the cross-sectional area of the annulus or ring; (5) the approach channel to the final (relatively) parallel lands should taper gradually to maintain melt compression and assist in welding together the melt streams after passing the mandrel spiders; (6) the die lands must be long enough to exert back pressure on the melt and to help eliminate weld lines; (7) the mandrel tip and the plane of the die face must be in-line; if the mandrel is projecting or recessed, drag marks may be apparent in the bore of the extruded tube; drag marks should be avoided since many plastics are highly notch sensitive; (8) there must be provisions for applying air through the mandrel or alternatively a vacuum chamber for use with sizing devices; an easy accessible hole of about 0.25 in. (6.4 mm) in diameter is usually sufficient; during processing this hole must not be partially or completely plugged; and (9) die should be snug enough to prevent leaking and yet free enough to be moved for adjustments. See **die-head mandrel cooling, internal.**

extruder pipe and tubing die design The crosshead die does not include spider supports to the mandrel. A mandrel is used to control the inside diameter (ID) of the pipe. The potential weld lines caused by the spiders in the in-line die are eliminated; but it has a weld line. After the melt splits going around the mandrel, the split makes contact to form the weld line. With both types of dies, the design of dies and careful processing procedure can practically eliminate the problem of the weld line. The weld lines can cause reduction in strength properties. The die cores or mandrels forming the inside shape of an in-line are supported on some type of spider, which divides the flow at the rear of a crosshead (also called *side-entry*) die. There is a thrust due to the drag of the melt on the core that has to be considered in the structural integrity of the die. Fortunately with these circular dies, draw down does not distort the extrudate but evenly reduces the pipe's OD, ID, and thickness. The dimensions of the die and the relation between output and haul-off rate then determine the final dimensions. See **extruder wire and cable die.**

extruder pipe and tubing die mandrel See **design pipe; mandrel.**

extruder pipe, cooling-tank weir An aperture on the end of a water cooling tank that is used to control the water overflow into the drain. Weirs are usually shaped to the extrudate shape.

extruder, planetary screw See **screw, planetary.**

extruder plasticator See **plasticator; screw length-to-diameter ratio.**

extruder plastomer Instrument used to determine melt flow index (MFI). See **rheometer, capillary on-line; test, melt flow.**

extruder plucking Extrudate that looks like a long needle has been stitched on it.

extruder postforming The special processing that may be done to the extrudate, usually just after it emerges from the die but before the plastic has a chance to cool. It provides performance and cost advantages, principally for long production runs or special orders. The technique is used with products such as tubes, profiles, sheet, and film. On leaving the extruder's die and while it is retaining its heat, the plastic is continually postformed producing products such as small or large (up to at least 4 ft (1.2 m)) corrugated tubing or piping. Moving split molds operating like a caterpillar have the moving corrugated mold cavities closed while the tube or pipe passes with each mold half, providing vacuum pressure and required water cooling internal tubing. Near the end of the line, the mold positions start separating to start releasing the corrugated product and gradually open the two-part molds. With these types of in-lines, the hot plastic is cooled only to the desired heat of forming. All it may require is a fixed distance from the die opening. Cooling can be accelerated with blown air, a water spray, a water trough, or their combinations. This equipment requires precision tooling with perfect registration. See **forming; postforming; thermoforming.**

extruder preheating See **heating, pre-.**

extruder pressure-head safety A working head-pressure indicator provides useful information to the extruder operator. Head pressure is the pulse of the extruder, so any surging shows up as a pressure fluctuation on the high stroke. See **extruder melt-flow oscillation; extruder surging; transducer, pressure.**

extruder process control Controls that account for all the action, starting with material handling and delivery to the extruder to the end of the line (train). Control programmers and data acquisition systems are continually being developed. See **control actuator; control drive, optimized; microprocessor control; process control; rheometer, capillary online.**

extruder process control safety See **programmable-controller safety.**

extruder processing See **FALLO approach.**

extruder processing window See **processing window.**

extruder profile The outline of a shape that is extruded. Pipes and tubes are classified as a separate category because they represent a specific major market. Profiles normally identify shapes that are noncircular or symmetrical. However, extruded products, such as capillary tubing, also are usually called a profile. They can be solid, hollow, or a combination of solid and hollow. Popular shapes include many hollow sections, such as window-frame profiles, tapes, edgings, gaskets, rods with different cross-sections, and structural shapes in the form of Ts, Us, Is, Hs, and squares. The product shapes and sizes are as limitless as the number of applications. Also called *shaped extrusions.* See **rod stock.**

extruder profile, coated An important profile product line is the coating of different profile-shaped materials. These substrate materials include wood, aluminum, steel, and other plastics. These profiles can also be called *coated products.* Extruders also can feed reinforced plastic (RP) pultrusion (profile) dies. RP pultrusion, in contrast to extruding profiles, is a process by which a combination of liquid plastic and reinforcement (continuous fibers, ropes, tapes, etc.) is pulled continuously through a heated crosshead die having a specific structural shape (Ts, Us, Is, Hs, squares, etc.). The fabricating process for the very big markets, where only plastic profiles are produced, is a takeoff of the method used in processing pipes and tubes. Most profiles are extruded horizontally through dies similar to the parts cross-sections. The extrudates are cooled and sized with air jets, water troughs, cooling sleeves, mechanical aids, specially designed frames, dimensional measuring devices, or their combinations. Flexible to rigid shapes are produced that at the end of the line are coiled or cut to required lengths. See **impregnation; extruder coating and lamination; extruder wire and cable.**

extruder profile, die An extruder die is usually massive, with an orifice that is oversized to the shape and size of the required contour. The final shape develops downstream from the die as the plastic expands, warps, or shrinks. The best designs are based on past experience with a particular profile shape. See **design die; die.**

extruder profile, free For simple shapes such as solid and V profiles with no close tolerance requirements, a free extrusion technique can be used. The plastics processed are those with high viscosity and softer grades, particularly when extruding at the lowest possible melt temperature. They can be used for short runs and prototyping with inexpensive dies that can, in many cases, be made from flat plate dies. For long runs these plate dies have the disadvantage of encouraging a buildup of stagnant plastic on the rear of the plate and eventually degrade the plastic producing unacceptable profiles. Usually no melt degrading problem develops before the short run is completed. If the problem starts developing or the run is completed, the die is dismantled and cleaned.

extruder profile plant Much profile manufacturing takes place in small, specialized plants. An important and rather large market exists in the short runs. The profiles may be small and require only small extruders. These plants usually design their dies and have their own machine shop make the dies. They may also do their own plastic compounding since many runs are limited but exchanges in profile shapes may be extensive. Setting up these lines for the small operations generally requires personnel with experience and skill.

extruder programmable controller safety See **programmable-controller safety.**

extruder purging See **purging.**

extruder, ram A ram extruder moves the plastic through a barrel and die by means of a ram (also called *plunger*) rather than the usual screw. It is used when a melt cannot be processed through a screw extruder. Ram extrusion, also *ram injection molding,* dates back to at least 1872, when cellulose acetate first was processed. The screw method of plasticizing took over early in the twentieth century since it provided a better method of melting and processing for practically all plastics. However, the ram method is still used for plastic melts that are not meltable in a screw such as PFTE and certain very heat-sensitive plastics. See **injection-molding machine, ram; injection-molding ultrahigh molecular weight polyethylene; polyethylene plastic, ultrahigh molecular weight.**

extruder ram, reciprocating A process that uses two ram extruders to produce a continuous extrudate through a die that is fed from both rams alternately.

extruder, reactive-processing The performance of chemical reactions during plastic processing. The most common reactants are plastic or preplastic melts and gaseous, liquid, or molten low-molecular-weight compounds. A particular advantage of the extruder as a chemical reactor is the absence of solvent as the reaction medium. No solvent-stripping or recovery process is required, and product contamination by solvent or solvent impurities is avoided. The chemical reaction may take place in the melt phase or, less commonly, in the liquid phase, as when bulk polymerization of monomers is performed in an extruder, or in the solid phase, when the plastic is conveyed through the extruder in a solvent slurry. The types of reactions developed include bulk polymerization, graft reaction, interchain copolymer formation, coupling or branching reaction, controlled-molecular-weight degradation, and functionalization or functional-group modification. Also called *reactive compounding, reactive extrusion,* or *reactive extrusion* (REX). See **chemical reaction.**

extruder, reactive versatility The extrusion device as a reactor combines several chemical process operations into a single piece of equipment with accompanying high yields of product. An extruder reactor is ideally suited for continuous production of plastics after equilibrium is established in the extruder barrel for the desired chemical processes. Because of their versatility, most extruder reactors are twin-screw extruders that possess a segmented barrel, each segment of which can be individually cooled or heated externally. In addition to external heating, a molten plastic may be shear heated by the resistance of viscous plastic to the conveying motion of the screw; these processes provide energy for chemical reaction. Extruder screws often have specialized sections or configurations, such as high shearing sections. Twin-screw extruder screws may be equipped with interchangeable screw elements that provide different degrees of mixing and surface-area exposure by varying the depth between screw flights, the individual flight thickness, and direction and degree of flight pitch.

extruder reduction gear A gear device (gear reducer) that is used to reduce speed between the drive motor and screw. Supplementary speed reduction means may also be used, such as belts and sheaves.

extruder rheometer See **rheometer.**

extruder roll A roll that is used on lines for films, sheets, coating, and so on. They include winders, dancer rolls, lip rolls, spreader rolls, textured rolls, engraved rolls, and cooling rolls. All have the common feature that they are required to be extremely precise in all their measurements, surface conditions that include commercial-grade mirror finishes, center line with tolerance operations, bearings and all ancillary mounted on journals, and rotating speed. They can be low in weight to at least 15,000 lb (7 ton) with diameters at least up to 60 in. (150 cm) and widths at least up to 30 ft (100 m). Some rolls require roundness and surface finishes to be within 0.00005 in. (0.00127 mm). Many winders offer sophisticated features and are highly automated, but some are designed to answer the need for simplicity, versatility, and economy. Surface winders have a gap-winding ability for processing tacky films such as EVAs and the metallocene plastics. The controls and uniformity of speed in many operations are critical. See **tolerance, full-indicator-movement.**

The winders roll a continuous film or sheet into certain weight (lb or kg/ton) or diameters on spools or reels. Material speeds are up to at least 2,200 ft/min (670 m/min) in cast-film lines and at least 1,000 ft/min (330 m) in blown-film lines. Blown-film lines may want to use reverse winding systems to allow coextruded films to be wound with a particular material as the inside or outside layer. Throughputs are over 2,200 lb/h (1,000 kg/h). Transfers from one roll to another can take less than a second. See **calendering, controlled nip pressure in; extruder godet unit; roll.**

extruder roll, adjustable Manual-adjustment systems include the dancer roll, canvas drag brake, various pony brakes, and pneumatically operated brakes. The most expensive is the regenerative-drive system with transducer rolls and dancer rolls a close second. These systems are usually required in high-web-speed applications where accurate tension control of expensive or sensitive material is paramount. With roll-windup systems, different roll or reel-change systems are used to keep the lines running at their constant high speeds.

extruder roll coating, kiss A roll arrangement carries a metered film of very thin plastic coating to the web. At the line of web contact, the film is split, with part of the coating remaining on the roll and the remaining adhering to the web. See **extruder coating and lamination.**

extruder roll, compounding See **compounding, shear-roll; mixer.**

extruder roll cooling Roll- or drum-cooling systems range from an inexpensive, rather poor, nonuniform surface temperature control to rolls suitably cored to permit controlled circulation of cool water, expensive, and very uniform surface temperature control. When sizing chillers, the heat generated by the pumps needs to be accounted for. For example, a 20 hp water pump can require up to 4 tons of additional chilling capacity to remove the heat generated by the pump. See **chill; coolant; extruder film-cooling roll versus quench-tank; roll.**

extruder roll, dancer The dancer rolls can be used as a tension-sensing device in film, sheet, and coating (wire, film, etc.) lines. They provide controlled rate of material movement. The type of roll can influence the roll's performance. As an example, chrome-plated steel-casting drums would seem to be very durable dancers, and if used in the absence of a nip roll, they seem as though they should last many years. However, these rolls are in fact very soft due to the annealing that good rolls receive for stress relieving the steel. A situation can occur where a casting drum has been coupled with a steel chill roll to nip polish a cast-film web. The casting drum was imprinted by hard plastic edges or die drips. This action occurs because the compressive stresses in a solid plastic that is passing through the nip roll will exceed the yield strength of the relatively soft steel-drum surface. Higher line speeds make the problem worse. To prevent this damage, the roll must be hardened.

extruder-roll decorating When the melt leaves the die and enters roll nips, it is soft enough to take the finish of the rolls it contacts. Thus, in addition to smooth and highly glossy finishes, textured or grain rolls can be used. They can impart a mirror image. They can give both functional and aesthetic qualities to the film or sheet. Grain design is limited only by the imagination. See **decorating; embossing.**

extruder roll, embossed See **embossing; extruder roll decorating.**

extruder roll nip See **calendering, controlled nip pressure in.**

extruder roll nip safety See **nip.**

extruder roll plating See **chrome plating.**

extruder roll preheater A heated roll installed (for example, in a coating line) between a pressure roll and unwind roll whose function is to heat the substrate prior to being coated. See **heating, pre-.**

extruder roll printing See **printing, gravure.**

extruder roll spreader or expander Types of film spreaders or stretching rollers include grooved metal idler rollers, expander rollers, and spreader rollers. The grooved roller has opposing, etched spiral grooves that start at the roll's center and spiral toward the ends. As the roll turns, air flows and follows the direction of the grooves along the metal surface. Because of the grooves, flow is generated and moves from the center of the roll outward. This action forces any web wrinkles out toward the ends of the roll. The major advantage of these rolls is that they are free turning and that existing idler rolls can be easily modified. However, as the web's processing speeds increase, these rollers gradually lose their effectiveness. Because the roll has a smooth surface, it has a low coefficient of friction. Subsequently, as the line speeds increase, so does the air flow, causing the web to slide over without making complete contact with the roller. If the roller does not make contact with the web, it does not rotate. So its ability to remove wrinkles is affected. The surface of this type of roller also has other limitations for certain applications. For film metallized or printed and coated webs, the roller's hard surface can produce undesirable marks on the substrate as it passes the grooves.

The expander film-spreader roller consists of a flexible center shaft, a series of bearings placed along the shaft, a flexible metal inner covering, and a smooth-surfaced, one-piece elastomer outer covering. This bowed roller removes wrinkles by creating an ever-increasing skew or angle on the roller's rotation, which provides a shift in web direction from the roll's center outward toward the ends. Its major benefit is that the roller crown or skew can be adjusted while the line is running to shift the orientation of the web as it passes over the roller. However, the bowed roller design can alter the natural flow of the web, creating uneven tension across the face of the roller, resulting in possible drag in the processing line. This action can cause the web to stretch and distort, especially with thin films. Rollers require a specific amount of space to provide optimum performance.

The expander roller (or spreader roller) originally consisted of metal or wooden slats with internal elastic bands connected to angled end plates. The connection of the bands to the pitched end plates caused the bands to expand in the center section as the roller rotated. There was a pulling apart of the slats to provide a spreading action. Among several variations are some with internal mechanisms. The next generation eliminated the metal and wood slats and replaced them with more substantial elastic cords. However, they are still attached to the pitched end plates. With these expander rollers, the substrate enters at a point where the cords are relaxed and then exits at the point of maximum cord expansion to achieve web spreading. The amount of spreading action can be adjusted by changing the angle of the roller's end plates. The direct elastic cord and substrate contact provide better coefficient of friction and are less abrasive than the metal or wooden slats.

However, while these rollers offer adjustable spreading action, they eventually lose their effectiveness because the rubber cords do not fully recover to their original state after continuous stretching. Another limitation is that at high film speed, air enters between the elastic bands and is trapped under the web. This will cause the web to float over the roller surface, negating its function. There can also be web markings. One of the latest generation operates on the same principle but features a stretchable one-piece rubber sleeve supported by a series of brushes. As the roll rotates, the entire roller sleeve, as opposed to individual cords, expands and contracts to provide spreading action. The two factors of the wrap or angle at which the web enters onto the roller, and the angular displacement of the end caps control the amount of spreading. Notable advancements in this expandable sleeve roller include a smooth, continuous surface that does not produce markings or allow air to enter under the web. However, the stretching of the rubber still causes the roller to eventually wear over time.

extruder roll tension control A potential major trouble spot is material tension control. There is a proportional relationship between winding tension and lay-on-roll forces. For example, wrinkles may be the result of an alignment problem. Winding shafts are potential problem areas where bumps and valleys develop. Various tension-control techniques are available. The proper selection involves decisions on how to produce the tension, how to sense the tension, and how to control the tension. The tension-system selection process depends primarily on the data sensitive to the application. For instance, if the material has a very low tension requirement and if exact control is required, then perhaps using a magnetic particle brake with an electrical transducer roll with appropriate electronic control is best. However, if the material is on large-diameter rolls and moves at slow speed, then a roll follower system can be used effectively. See **extruder-web tension control; extruder-web tension control, slipping and tearing; extruder-web stretching and tearing; tensile strength.**

extruder-roll torsional wind-up See **torsional wind-up.**

extruder roll winding chuck A device that supports an arbor, mandrel, or core for rotation to wind film and sheets. Chucks are generally used in pairs, with one supporting and driving and the other supporting and idling.

extruder roll winding strain Winding strain that can occur at the end of the line and that turns a wound roll of film into corrugated hard rock in a few days. This action is caused by several factors: (1) Trapped air as the roll is being wound makes a roll feel soft. Static charges help trap air. Lay-on rolls help to squeeze air out but can also create other problems. The rapid escape of air can produce telescoping. (2) Tension creates a compression load, which squeezes out the very thin film of air, crush underlayers, and crush cores. Tension also tends to even out some of the wrinkles and irregularities. (3) Room-temperature-recoverable strains are residual processing strains that release themselves at room temperature to produce stress or shrinkage. Techniques are available for predicting the level of room-temperature-recoverable strains. (4) Crystallization of crystalline plastics also produces shrinkage of a magnitude of generally ½ to 2%. Crystals take less space, and thus, as the crystal structure goes to completion, shrinkage occurs. Crystalline plastic rolls are permitted to shrink for about one to two days and then are slit and rewound. See **strain; tensile strength.**

extruder safety See **barrel-venting safety; safety and machines; safety interlock; safety, machine-lockout.**

extruder salt bath See **salt bath.**

extruder scrap See **cut, kerf, and registration.**

extruder screen pack Melt from the screw is usually forced through a breaker plate with a screen pack. Extra heat develops when melt goes through the screens, so some heat-sensitive plastics cannot use a screen pack. The function of a screen pack is to reduce the rotary motion of the melt, remove large unmelted particles, and remove other contaminants. This situation can be related to improper screw design, contaminated feedstock, poor control of regrind, overheating melt, and so on. Sometimes screen packs are used to control the operating pressure of extruders. However, processing with matched and controlled back pressure and operating within the required melt pressure and temperature can facilitate mixing, effectively balancing out melt-heat problems. In operation, the screen pack is backed up by a breaker plate that has a number of passages, usually many round holes ranging from $^1/_8$ to $^3/_{16}$ in. (3.2 to 4.8 mm) in diameter. One side of the plate is recessed to accommodate round disks of the usual wire cloth, which make up the screen pack. When using fine screens in a pack, use a coarser screen as the first upstream screen to catch large dirt particles and to also support the following finer screens. See **injection-molding screen pack; screen pack.**

extruder screen-pack operation To help prevent screen blowout, back-up fine screens and use progressively coarser ones downstream. Pressure controls should be used on both sides of the breaker plate to ensure that the pressure on the melt remains within the required limits. The number of screen openings per linear inch (or 2.54 cm) determines the mesh number. Therefore, particle size increases with decreasing mesh size. Based on the processing requirements, the screen changers may be manual to highly sophisticated automatic continuously moving devices. See **screen-pack breaker plate.**

extruder screen-pack operation, automatic When adding an automatic screen changer to a new or existing extruder, the screw needs to extend into the screen-changer body. This extension is needed to eliminate the existence of additional plastic inventory, which would require additional soak time during startups. The screw should be extended to within $^1/_4$ to $^3/_8$ in. (6 to 9.5 mm) of the breaker plate. It should be either nonflighted or, preferably, flighted with the extended portion of flights undersized from the main flight diameter by 0.015 to 0.020 in. (0.4 to 0.5 mm) per side. The reason for the nonflighted or undersizing of the flights in the extended area is that the entrance bore of the screen changer is not hardened like the barrel liner. Otherwise, the flights will gall in the bore of the screen changer.

extruder screw See **screw.**

extruder, screwless A device that is used principally for R&D and is of various designs, such as rotating drums, slit or stepped plates and disks, or conical rotors with eccentric barrels. A screwless extruder can have varying gradual clearance between barrel and rotor or plates to plasticize (melt) the thermoplastic by frictional heat. Designs to increase their output include using a screw extended from the center of the rotor or a doctor blade transferring melt through a slit-die opening. Different designs of this isothermal system are targeted to reduce processing energy consumption, reduce and provide more uniform shear to improve properties, reduce residence time, and so on.

extruder screw pulling A step in the cleaning process. Even though it is called pulling the screw, removal starts by using a screw pusher. It is inserted through the hollow drive shaft at the rear to push on the shank of the screw after the die, breaker plate, and so on are removed from the front end. More often, the pusher is a threaded shaft that is attached to the rear of the extruder. The screw is jacked out of the barrel using the screw drive for power. The screw is conveniently cleaned while it sticks out of the barrel. See **cleaning; injection-molding screw pulling; screw removal; stripping fork.**

extruder-screw reverse flight See **screw reverse flight.**

extruder-screw speed The usual rotation is at 25 to 600 rpm and starve-fed. Speed depends on screw diameter and also particularly on melt characteristics. See **injection molding screw rotation speed; screw rotation speed.**

extruder sequential molding See **blow molding, extruder-sequential.**

extruder shark-skin surface A surface irregularity in the form of finely spaced sharp ridges that is caused by the relaxation effect of the melt, particularly during extrusion. During melt flow through a die, the melt next to the die surface tends not to move, whereas that in the center flows rapidly. On leaving the die, its flow profile is abruptly changed to a uniform velocity. This change requires a rapid acceleration of the surface layer, resulting in high local stress. If this stress exceeds some critical value, the surface breaks, resulting in a rough appearance called *shark-skin*. With the rapid acceleration, the deformation is primarily elastic. Thus, the highest surface stress and worst sharkskin occurs with a high modulus and high viscosity melt or in high molecular weight of narrow MWD at low temperatures and high extrusion rates. The addition of proper die-lip heating to reduce viscosity is an example of how to reduce the defect. See **molecular-weight distribution; shark-skin surface.**

extruder sheet Sheet extrusion transforms thermoplastic materials into roll or sheet stock through a combination of heat and pressure. The extruder plasticizes the plastic, pumps it through a die, and continues downstream in the sheet line. The term *sheet* or *sheeting* normally describes a flat plastic product that is 0.010 in. (0.25 mm) or greater in thickness. Some industries use 0.004 in. (0.10 mm) as the dividing line between film and sheet. Widths can be up to at least 10 ft (3 m). Sheet-extrusion technology produces single- (mono-) layer products to the more complex coextruded or multilayer engineered products. Three primary techniques are used to manufacture plastic sheets: (1) in by far the most popular, plastic is extruded through a flat die onto polished rolls that could include the use of an air knife; (2) when extrusion is through an annular pipelike cross-section die onto a sizing mandrel, the extrudate is slit in one or more places and then flattened via rolls into a sheet [very popular in foam sheet production]; and (3) calenders are used.

A typical extrusion sheet line (train) consists of a properly controlled extruder, sheet die, temperature-controlled (individually heated or cooled) polishing three-roll stack (stand), take-away equipment (such as gauge monitors and controls, edge trimmers, antistatic devices, air coolers, cooling tunnels, conveyors, slitters, pull or nip rolls, tension rolls, or cross-cutting devices), and either (turret) wind-up or stacking equipment. Throughput capacities for these lines can be up to at least 900 to 2,500 lb/h (400 to 1,100 kg/h). Winders can run up to at least 250 ft/min (75m/min). Stack rolls are usually of double-shell design, giving internal high-velocity liquid circulation at a controlled temperature. Each roll is equipped with its own individual temperature control system, which is built into the take-off unit. The sheet gradually cools as it travels around the rolls becoming sufficiently solidified so that it can continue down the line. After leaving the usual three-roll stack, the sheet cools further as it travels down the line being pulled by pull rolls located downstream. This approach permits very fast and efficient temperature-control response. See **calender; roll stand; sheet; troubleshooting optical sheet.**

extruder-sheet air knife A device that provides a means to produce plastics such as PP sheet on a conventional three-roll sheet line. Air knives are also used in other extrusion lines, including cast film, coating, and lamination. The air knife ensures positive and firm positioning of the sheet against the roll. Automatic die-lip adjustment is used. High-efficiency internal design provides precise pressure uniformity and optimum air impingement. Some designs quickly position into and retract out of the open upper roll gap of the downstack three-roll take-off. Micrometer-type adjustments permit optimization of the air position and impingement angle, making the sheet conform to the middle roll for uniform cooling.

extruder-sheet antistatic bath A bath that is used when the surface application of a slip agent is required to aid sheet-product denesting or to protect against static dust pick-up. These baths need to be easily and quickly installed and removed.

extruder-sheet blocking See **sheet blocking.**

extruder-sheet choker bar An extension into the flow channel within a die to produce a balanced melt flow and equalize melt pressure across the die resulting in improved thickness control across the sheet. Also called *restrictor bar.* See **die restrictor bar.**

extruder sheet, coextruded See **coextrusion.**

extruder-sheet line component Different and important components of the sheet extrusion lines follow the dies and must be properly aligned and interfaced with each other. Equipment should be properly matched, easily maintained, have rigid-frame construction, have roll-bearing assembled units with the capability to minimize play and deflection, use self-lubrication, and so forth. See **roll stand.**

extruder-sheet neck-in See **extruder neck-in and beading.**

extruder sheet, optical See **troubleshooting optical sheet.**

extruder-sheet orientation See **orientation, tenter frame and roll.**

extruder-sheet tension control See **extruder-web stretching and tearing; extruder-web tension control, slipping, and tearing.**

extruder-sheet thickness See **die, film and sheet thickness for a; optical monitoring.**

extruder-sheet three-roll stack See **extruder sheet.**

extruder, single-screw Popular single-screw types that use conventional designs with uniform diameters of the screw and barrel, have decreasing screw-channel volume, continuous variable speed, pressure control, and a venting (devolatilization) system. Special designs use conical or parabolic screws for special mixing and kneading effects and include eccentric cores, variable-pitch superimposed flights of different pitch, kneading rotors, fitted-core rings, periodic axial movement, and so on. Barrels may have internal threads, telescopic screw shapes, feeding devices, and so on. See **barrel length-to-diameter ratio; compounding; extruder, multiple-screw; extruder reactive versatility; extruder, twin-screw; screw.**

extruder, slot A method of extruding film or sheet in which molten plastic is forced through a straight slot onto a conveyor belt.

extruder, solid-state (SSE) A method of deforming and evaluating uniaxial molecular-chain orientation and extension for a wide range of crystalline and amorphous plastics. For example, via SSE investigation, HDPE can be drawn into fibers having very high specific tensile moduli and strength. A highly oriented extrudate can be obtained by extruding through a capillary rheometer with a conical die at temperatures close to the melting point. Initial work led to the development of transparent and fibrous linear extrudates in melt heated and cooled states. See **fiber processing, solid-state extrusion.**

extruder specification A requirement that includes factors such as screw design, type of controls, drive power, and output rate relative to operating cost. Cost includes the usual machine, electric power, labor, plant overhead, maintenance, downtime, and so on. Note that the greater output capacity of a specific and more expensive machine that meets performance requirements justifies its purchasing cost because it produces more profit. Greater capacity is obtained without additional labor costs, production costs, and so on, provided the machine is properly operating. See **electric motor; specification.**

extruder specification drive In choosing the size of an extruder and its driving mechanism, considerations to be evaluated include (1) the range of speed that the screw will operate at, (2) the variation speed levels or ranges,

(3) the maximum power that is required from the drive based on the plastic to be processed, (4) the relationship required between the screw speed and the torque on the screw shaft, and (5) whether the machine is to be used for single or multiple products. The drives consist of motor or belt drives, which are linked to the screws through systems such as double-reduction gearboxes. Belt drives are used for the smaller machines. The drive simplifies the transformation of high motor speeds into lower speeds and high torque required to operate and control the screws. See **electric motor.**

extruder specification feed system The transmission of torque to the screw shaft and the axial thrust bearing. Torque can be transferred from the gearbox shaft by means of a key or slot. Usually the better method is via a coupling sleeve with longitudinal splines, which require a push-fit onto the screw shaft. The different arrangements between gearboxes and screw shafts have their advantages and disadvantages. The feed box and barrel of the extruder form the casing for the screw. The screw must fit closely into the inner wall of its barrel so that the material feeding, pumping, and plastifying actions are accomplished efficiently. The clearance between screw and barrel varies depending on the plastic to be processed and the capability of the extruder. The essential factor in the pumping action during the extrusion process is the interaction between the rotating flights of the screw and the stationary barrel wall. If the plastic is to be conveyed at all, its frictional buildup must be low at the screw surface but high at the barrel wall. If this action does not occur, the plastic may rotate with the screw and not move in the axial direction to exit the die. It is usually an advantage to have automatic feeding with controlled fill levels weightwise. With this action, relatively small hopper capacities are sufficient. See **screw; screw torque.**

extruder startup See **extruder operation startup.**

extruder, starve-feeding See **material starve feeding; venting feeder.**

extruder static mixer Most extrusion operations involve either the processing of regrinds with virgin plastics and the addition of color. Uniform mixing of the feed mix is necessary to achieve acceptable product properties, but as output rates increase, uniform mixing becomes more difficult. Head pressure and stock temperature must be held constant to maintain extrudate control. More extruders are being equipped with a static mixer to overcome some of these problems. These mixers are located at the end of the screw before the screen changer or die. If a gear pump is used, the static mixer is located between the screw and gear pump. Static mixers contain a series of passive elements that have been placed in a flow channel. These elements cause the plastic compound to subdivide and recombine to increase the homogeneity of the melt. There are no moving parts, and only a small increase in the screw energy is needed to overcome the resistance of the mechanical baffles. The installation of a static mixer increases the effective length to diameter ratio of the extruder and usually results in some increase of the melt temperature and head pressure. The overall result is a more homogeneous melt and a more stable extrusion process with less output surge. Sufficient heat-up time should be provided with startups of the extruders when using static mixers. To prevent excessive pressure and damage to the extruder during startups, the screw's rpm should be kept low until plastic flows uniformly from the die. See **static mixer.**

extruder statistical assessment See **statistical assessment.**

extruder surging Unstable pressure build-up in an extruder that leads to variable throughput and waviness in the output product's appearance.

extruder swell See **design, basics-of-flow die.**

extruder take-off winder Downstream of the die different types of auxiliary equipment are used to meet different requirements. They include extrudate pull devices (pinch rolls, caterpillar/pair of diagonally moving belts, sizing fixtures, cooling tanks, coiling devices, line-speed controls (mechanical or sonic), tension controls (capstan, etc.), and inline cutters.

extruder take-off winder emergency stop An emergency stop device for a winder prevents inadvertent indexing while the operator is working between rolls. This device should be located in reach of the operator, who may be under a single turret or between dual turrets.

extruder, tandem Two extruders work together to provide special processing techniques to produce products such as extruded foamed plastic.

extruder temperature See **melt-temperature effectiveness.**

extruder thermoforming line A continuous operating line that is used where sheet or film extruded is in-line with downstream thermoforming equipment. See **thermoforming.**

extruder thread-up See **extruder operation startup.**

extruder tube, blown A blown thin-film tubing that is produced by extruding a tube, applying a slight internal pressure to expand it while still molten, and then subsequently cooling it to set. Different shapes can be formed, such as circular or longitudinal corrugations. If desired, it can be flattened, prior to setting, through guides and wound up flat. See **extruder-blown film; postforming.**

extruder tubing See **extruded pipe and tubing; tubing, microbore.**

extruder, twin-screw (TS) Although there are fewer twin-screw extruders than single-screw extruders, they are widely employed for difficult compounding applications, devolatilization, and other special operations. The popular common twin-screw extruders (in the family of multiscrew extruders) include tapered screws with at least one feed port through a hopper, a discharge port to which a die is attached, and process controls such as temperature, pressure, screw rotation (rpm), melt output rate, and so on. Twin-screws with intermeshing counterrotating screws are principally used for compounding. The three that are available commercially include corotating and counterrotating intermeshing twin screws and nonintermeshing twin screws with counterrotation. There are fully intermeshing and partially intermeshing systems and open- and closed-chamber types. In the past major differences existed between corotating or counterrotating; today they work equally well in about 70% of compounding applications, leaving about 30% where one machine may perform dramatically better than the other. See **compounding; extruder, multiple-screw; extruder, reactive versatility; extruder, single-screw; screw.**

extruder, twin-screw, conical or parallel The market for counterrotating twin-screw (TS) extruders is dominated by two designs. One has cylindrical screws, and the other is fitted with conical screws. The superiority of the conical principle to parallel appears in the theoretical comparison and in practice. The flexibility of conical screws turns out an extrudate that is of consistent quality at both low and high output rates and that is not sensitive to raw-material fluctuations. It appears that the parallel screws have reached their efficiency limit unless a means of drastically increasing the screw torsional strength is developed. Conical design still offers more benefits through further development.

extruder, two-stage See **mixer, extruder; screw, venting.**

extruder vacuum box For certain lines, such as film, sheet, and coatings, a dual-chamber vacuum box is located just downstream of the die lips. It ensures that the exiting extrudate hot web from the die to its next position, such as a roll, is stable. With proper stability, the final product has quality control at this point in the line. The vacuum box is an evacuated chamber so that it will remove any air carried by the cooling roll and any airborne contaminants that may be near the roll surface. The second chamber controls the vacuum immediately adjacent to the melt curtain; by adjusting this vacuum, the angle of the melt curtain can be independently controlled. With this action, the melt is not dragged over the upper die lip, eliminating the potential die lines caused by the die lip. See **vacuum sizing.**

extruder valve An adjustable restriction to melt flow that is used to control back pressure in an extruder.

extruder variability See **extruder instability or variability.**

extruder venting During extrusion, as in other processes such as injection molding, melts must be freed of gaseous components (monomer, by-product gases, moisture, plasticizer, additive, air, etc.), so a vented screw or barrel can be used with or without prior drying of the plastics. See **injection-molding venting; screw pump ratio; screw, venting; venting.**

extruder, vertical An extruder that is arranged so that the barrel is in the vertical position rather than the usual horizontal position. It is used in certain wire-coating operations.

extruder web See **web.**

extruder-web stretching and tearing All plastics have some amount of elasticity associated with them. As long as the plastic stretches within its elastic limit, it will eventually return to its natural shape. If the plastic is overstressed, it reaches what is known as *plastic deformation,* meaning that the plastic will not return to its original shape. It is important to keep the drag force from feed-mechanism friction as low as possible and to keep acceleration of the feed material low enough so the product does not permanently deform or tear. Sinusoidal-acceleration profiles reduce the load on the plastic by providing gentle forces near zero speed and top speed while making up for lost ground in the middle with the result of diminishing stretching. Stretching also contributes to reduced accuracy. This situation can be overcome by either compensating for the stretch in the controller when the amount of stretch is predictable or by installing a position verification device between the feed mechanism and the postfeed process. See **deformation, plastic; elasticity; stress, elastic-limit.**

extruder web tension control Various tension-control techniques are available. The proper selection involves decisions on type of product, how to produce the tension, how to sense the tension, degree of tension required, how adjustments are to be made, how much tolerance control is to be correlated in the line (degree of sophistication required), type of sensors to be used, and how to control the tension. See **extruder flat-film tape; extruder roll, tension-control.**

extruder web tension control, slipping, and stalling Tension must be controlled at the web in a cut-to-length application. The basic three contributors to inaccuracies in cut length are material slippage, mechanical coupling slippage in the feed mechanism, and feed-motor stalling. All these problems can be detected with a position feedback device. A motion controller can monitor this information, correct for errors, or detect problems. Using position information, statistics can be generated to monitor quality of the finished product length. See **tensile strength.**

extruder web-thickness measurement See **sensor, film and sheet.**

extruder welding A joining process in which melted thermoplastic is extruded into a groove in a usually preheated seam. The melt fills the groove and cools, welding the parts together. See **welding.**

extruder weld line See **weld line.**

extruder wire and cable Wire and cable covering or coating in continuous lengths with plastics is an important application for extrusion. Large quantities of plastics have covered billions of miles of these products. This coating process produces many different types and sizes of products. The following three types are examples of coverings: (1) electrical insulation for copper wire, fiber optics, and so on (in conjunction with semiconductive inner and outer layers), (2) internal coverings and fillers (lapped or extruded), and (3) sheaths and external protective coverings. See **extruder wire coating, optical-fiber.**

The line is usually made up of an unwinding roll for the wire or cable followed by a tension-controlled input capstan, possibly a wire straightener, and wire preheater to travel through an extruder's 90° crosshead die where the plastic coating is applied. It continues through water or an air-cooling system for thermoplastics or a heating system for thermosets, testers, gauge controllers, tension output capstan, tension controller, and the windup roll. Different curing systems are used when TS material are being processed. They include hot-gas systems, vulcanization cures (TS cross-linking action for natural or synthetic elastomers), and others. There is also special equipment for certain plastics, such as nylon to maximize performance (toughness, stress relaxation, etc.) by using in-line annealing and moisture-conditioning equipment. The high and constant output rates of extruders with engineered upstream and downstream equipment make possible production of linear speeds at very high rates. The line's output rates can be at least 4,000 ft/min (1,300 m/min) for certain products. Thin wires, as reviewed, may be coated at up to 6,500 ft/min (2,000 m/min). See **electrical cable armor; fluid-bed process.**

extruder wire and cable capstan A large drum device that pulls extrudates by wrapping melt around the drum to provide sufficient friction to get a nonslip drive.

extruder wire and cable cross-linking polyethylene with peroxide Various systems are used to cure XLPE compounds, including steam, nitrogen gas, and pressurized liquid continuous vulcanization systems. The systems involve heat to cause the peroxide to decompose into a reactive radical and initiate the cure cycle forming a thermoset polyethylene plastic. See **catalyst, benzoyl peroxide; cross-linked polyethylene plastic.**

extruder wire and cable cross-linking radiation without peroxide Usually the coated wire does not receive the full dosage on the first pass through electron radiation because of the rapid temperature increase. It is festooned on a series of pulleys and passed through the beam several times until the desired dosage is reached. The usual peroxide curing agent is not needed, since radiation provides the same effect, but sometimes a cross-linked accelerator is added. This process is commonly used for appliance wire, control cables, and so on. See **cross-linking, radiation.**

extruder wire and cable die The usual die used is a cross-head with a 90° angle between the wire line and the extruder body axis. With this setup, the entire length of the extruder projects sideways from the coating lines. To help melt flow from developing dead spots in the melt channels, 30° or 45° cross-heads can be used. They provide a more streamlined interior, and the extruder location is better adapted to some plant layouts. They are sometimes preferred when processing PVC because of the streamlining and better control of the melts heat profile. Most dies are subjected to very high internal pressures since a coating pressure of over 5,000 psi (35 MPa) is required. See **die.**

extruder wire and cable die draw-down ratio (DDR) The ratio of the cross-sectional area of the die orifice or opening to the final extruded shape. To determine the DDR use the following equation: $DDR = (D_D^2 - D_T^2)/(d_{cw}^2 - d_{bw}^2)$; where D_T = diameter of guider tip, D_D = diameter of die opening, d_{bw} = diameter of bare wire, and d_{cw} = diameter of coated wire. If the DDR is too high, a rough surface or internal stresses in the coating will exist. As an example, a typical DDR value for LDPE is 1.5, HDPE is 1.2, PVC is 1.5, and nylon is 4.0. See **draw-down ratio.**

extruder wire and cable die draw-ratio balance (DRB) A guide in determining the minimum and maximum ratio values that can be used for different plastics. To determine the DRB, use the following equation: $DRB = (D_D/d_{cw})$ divided by (D_T/d_{bw}). The value of the DRB ranges around one ± (close to) one. Outside the set range limits can cause at least out of round and melt degradation. Plastics have different DRBs and DDRs, which can be used as guides to processability and to help establish their various melt characteristics.

extruder wire and cable process Different methods are used to process different plastics to meet different property requirements. Vulcanization is used to cure thermoset elastomers and rubbers such as SBR, IR, and CR (neoprene). Methods of vulcanization or curing include steam, liquid (eutectic mixtures), microwave, and hot air. Systems that are used to cure peroxide-based cross-linkable polyethylene (XLPE) compounds include steam cure, nitrogen cure, and pressurized liquid continuous vulcanization. All these methods involve higher heat than the melt heat to cause the peroxide in the plastic to decompose into a reactive radical and initiate the curing cycle. See **eutectic mixture; fluid-bed process; salt bath.**

extruder wire and cable process, continuous vulcanization (CV) A common method of curing. With this method, high-pressure steam contacts the wire and cable as it moves through the CV tube. Catenary CV lines are used in the manufacturer of large cables, such as 600 volt building wire or 15 KV power cable. The lines curve downward from a raised extruder horizontal platform and follow a bowed shape rather than a straight line. For the thickest insulated cables, a vertical CV system is used and will have a number of extruders supplying the appropriate melts for the overlapping layers. They are on a raised platform directly above the CV tube. The melt is extruded onto the conductor straight down to maintain concentricity. Because the cable is vertical, the cable never touches the sides of the tube.

extruder wire and cable process, dry cure The first nitrogen lines (N_2) became operational in the mid-1970s. Dry curing utilizes N_2 as the heating medium instead of pressurized steam. By using N_2, the processor avoids saturating the cable insulation with water. It also reduces the size and number of voids in the cable insulation. Some lines are capable of using either steam or N_2 as the curing medium. Other types of dry-cure systems have been developed, such as the high-velocity gas cure and radiation cure. The high-velocity gas cure is similar to the steam-cure system. Passing the wire or cable through a beam of electron radiation performs radiation cross-linking. Radiation curing is commonly used in the production of appliance wires and control cables. These applications, competing with other systems, are most suitable because of their relatively thin insulating layers. The materials used for this procedure are similar to those used in peroxide curing, except that the peroxide has been eliminated. In some cases, a cross-linked accelerator is added. The quality and physical properties of radiation cross-linked materials are virtually identical to those produced by peroxide curing. See **extruder back pressure relief port; extruder liquid-curing-medium; reinforced-plastic pultrusion.**

extruder wire and cable, ram An exception to the use of a screw-operating extruder occurs when a very low-melt plastic such as PTFE (polytetrafluoroethylene) is to be used where its specialty properties are needed. (Ram extrusion was first patented in 1872.) The PTFE do not easily melt, particularly in the production of heavy-wall PTFE wire coatings, so ram extrusion is used. Ram extrusion is used for these wire and cable jobs and also for producing rods, tubes, and large round solid "cakes" that are later skived to make PTFE film. With developments in equipment and the fluoropolymers that have high-melt viscosities, the maximum extrusion rate using screws is usually limited by melt fracture, particularly with the FEPs. However, these plastics have exceptional melt strength. This characteristic makes possible ram extruding using a die with a large opening and applying a draw down of the extrudate to the desired insulation thickness. See **film, skived.**

extruder wire and cable train The entire extruder line assembly that is utilized to produce plastic coated wire products (also other products).

extruder wire coating, optical-fiber Lines can usually operate at 100 to 200 m/min; with faster lines up to at least 400 m/min using high-speed payoff fiber accumulators that accommodate changing reels on the fly. Lines include 1.5 in., 24 L/D extruder, gravimetric feeder, fixed-center crosshead die, hot- and cold-water troughs, x-y diameter gauge and lump detector, and a Windows-based computer control with SPC and historical trending. See **fiber optic.**

extruder wood-plastic See **wood-plastic profile.**

extruder zero defect See **zero defect.**

extrusion In this book, the term *extruder* is used to identify the information pertaining to the process of extrusion. See **extruder.**

extrusion plastomer See **test, melt-index.**

exudation Migration of constituents (additives, solvents, plasticizers, etc.) from the interior of a fabricated product to its exterior surface. Also called *bleed out* or *sweating*.

Exxpol Exxon Chemical's trade name for its metallocene catalyst polymerization gas-phase processing system.

eyebolt See **mold eyebolt and hole.**

eye magnification See **macroscopy.**

F

fabric Any woven, knitted, felted, bonded, or knotted textile material. There are woven and nonwoven fabrics. See **fabric, nonwoven; fabric, woven; fiber processing.**

fabricating In this book, *machine, manufacturing, fabricating equipment*, and *process* relate to each other and are used interchangeably, as they are throughout the world of plastics. See **automation; clean-area fabricating; communication protocol; ergonomic; computer batch processing; computer monitoring information; control drive, optimized; controller; control-system reliability; DART software; designing processes with models; design, medical-device; design, plant layout via computer; device, smart; directional property; fabricating outsourcing; fabricating process type; fiber processing; machining processing; manufactured cost; manufacturing execution system; motion-control system; noise; operation, automatic; operation, manual; operation, secondary; operation, semiautomatic; optical comparator; orientation; pilot plant; plant; plant environment; plant operation; plastic consumption; plastic processing; plastics and the future; polymer, reactive; processability and molecular weight; process control; processing, art of; processing in-line; processing, intelligent; processing, intelligent communication; processing, intelligent systematic; processing rule; processor; production; production-control system; production data acquisition; production performance; production prioritizing; productivity; profit plan; project checklist; quality; quality system regulation; reinforced-plastic process; reliability; residence time; rheometer; safety; sampling plan; scale-up; statistical probability, six-sigma; statistical benefit; supply chain; technology assessment; test and classification; test specimen, processing; thermal diffusivity; tolerance molding; troubleshooting by remote control; Figure 3, Product Design Diagram Incorporating Process Selection; World of Plastics Reviews: Basics and Overviews of Fabricating Processes; World of Plastics Reviews; Making Marketing Work; World of Plastics Reviews: The Plastics Industry.**

fabricating and motion-control system (MCS) Demands on productivity call for more efficient and faster processes. In many cases, processes are becoming so fast that the asynchronous communication between traditional processor and motion-control system can become a problem. Deadlines for implementing MCSs are accelerated, and the system must be cost-effective and easy to integrate and maintain. See **motion-control system.**

fabricating, asynchronous A commercial method where data are sent when ready rather than being referenced to a timing clock or waiting until the receiver signals that it is ready to receive. See **warehousing.**

fabricating employment In the United States, annual workhours spent producing plastic products is estimated at 650 million, second to motor vehicles at 845 million. Following plastic products (in millions of hours) are aircraft at 570, commercial printing at 560, newspapers at 475, meat at 460, metal structural products at 350, and computers at 325. See **business; plastic industry; productivity; World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run; World of Plastics Reviews: Challenge 2000—Making Plastics a Preferred Material.**

fabricating, Finagle's law of The principle that once a job is fouled up, something done to improve it makes it worse. See **design features that influence performance.**

fabricating, integral Combining different parts of a product so that literally only one fabricated product is manufactured. Both the materials and the processes have to be understood simultaneously. Various devices and knowledge are available to help meet this task. See **FALLO approach; plastic processing.**

fabricating output The number of parts or length of a product that can be produced in a given time. System acceleration and top speed determine the output. If moves are short, acceleration will be the dominating factor. Short moves are defined as moves where acceleration and deceleration times are longer than the constant-velocity of the move. If a move is long, compared to acceleration time, top speed will have the stronger influence. Increasing speed means a faster motor or higher gear ratio; increasing acceleration requires more torque or lower gear ratios. For a given motor drive system driving the feed mechanism, the higher the system inertia, the lower the output. Also called *output, throughput*, or *flow rate*. See **extruder gear box; feeder; inertia; material feeding and blending; servo control.**

fabricating outsourcing Originally, buying rather than making parts. Now it encompasses the broader concept of using outside organizations to replace people, including entire departments and processes, such as data processing, telemarketing, and customer services. Also called *contract manufacturing* or *professional services*. See **business.**

fabricating process Many different processes are used to fabricate or manufacture plastic products. Choosing the optimum process encompasses a broad spectrum of possibilities. Sometimes only one process can be used, but generally options include reactive processing. Influencing the selection are quantity, size, thickness, tolerances, type of plastics, performance requirements, cost limitations, and so on. For example, plastics with fillers or reinforcements are generally far more stable in meeting tight tolerances. Processing may involve equipment that is simple to operate, or it may require extensive specialized equipment along with all types of auxiliary equipment. See **computer-integrated manufacturing; computers and statistics; DART software; FALLO approach; just-in-time; material handling; melt elasticity; melting temperature; mold cooling rate; molecular microstructure; morphology and mechanical property; plant control; plastic processing; polymer, reactive; processing window; production; production-control system; production data acquisition; production performance; reinforced-plastic process; rubber processing; standard industrial classification; ultrasonic fabrication.**

fabricating processing See **plastic processing; production.**

fabricating processing repeatability The ability of a system to bring the processing parameters to a desired position repeatedly. Because any system (equipment, materials, and controls in the plastics and other industries) will have inaccuracies or variabilities, repeatability is generally thought of as a range of ideal positions for a series of identical positioning command inputs. See **accuracy; repeatability.**

fabricating processing type Most fabricating lines incorporate both continuous and manual processes. Continuous processes include blow molding, calendering, compression molding, extrusion, injection molding, laminating, rotational molding, and thermoforming. Manual processes include casting, foam pouring, reinforced plastic processing, and welding. Fabricating lines include primary and secondary equipment. Primary equipment is required to produce the product. Secondary equipment is support auxiliary equipment used upstream and downstream of the primary equipment. See **auxiliary equipment; designing plant layout via computer; downstream; fabricating process type; train; upstream.**

fabricating process set point A predetermined process variable magnitude that the process controller targets or attempts to maintain. See **controller.**

fabricating process setting The preparation of a machine ready for processing. It involves the complete operation of setting machines in-line with other equipment (if applicable) to setting and adjusting all controls. Detailed instruction computer software or manuals should be available to provide instructions.

fabricating process type Many process names overlap since different segments of the plastics and other industries use them. There is also overlapping of terms such as *molds, dies, tools, molding, embedding, casting, potting,* and so on. Extrusion involves the use of both continuous and noncontinuous processing methods. Continuous extrusion processes include blown film, flat film or sheet, wire coating, continuous injection molding, and so on. Noncontinuous extrusion processes include injection molding, injection blow molding, injection compression molding, and so on.

Plastics fabricating process names include the following: adiabatic extrusion, adiabatic injection molding, adiabatic processing, advanced composite molding, air floatation, airmold gas-assist injection molding, autoclave adhesive bonding, autoclave molding, autogeneous extrusion, automatic extrusion, automatic molding, automatic processing, auxiliary equipment, backmolding (Hinterspritzen), bag molding, biaxially oriented extrusion, biaxially oriented molding, bladder molding, blister process, blow molding (different types), blown film, bridge reinforced plastic, bulk-molding compound, bulk-molding compound injection molding, cable extrusion, calendering (different types), carded package, carousel molding, casting (different types), C-clamp injection molding, cellular plastic molding, cellular chemical blow molding, centrifugal casting, centrifugal molding, ceramic-plastic molding, chemical vapor deposition, cladding, closed molding, coating (different types), coextruded foamed blow molding, coextrusion, coextrusion capping, coining, coinjection foam molding, coinjection molding, cold-flow molding, cold forming, cold heading, cold molding, cold-press molding, cold stamping, cold working, combiform, comoforming cold molding, compounding, compound molding, composite molding, compreg molding, compression-injection molding, compression molding (different types), computer-aided extrusion, computer-aided molding, computer-aided processing, contact molding, contact-pressure molding, continuous coating, continuous fiber spinning, continuous injection molding, continuous laminating, continuous molding, continuous strip molding, controlled-density molding, copolymer molding, corrugated pipe extrusion, corrugated multilayer pipe extrusion, counterpressure intrusion, counterpressure molding, cross-flow molding, cross-laminating, decompression molding, devolatilizing extrusion, devolatilizing molding, die casting, die-slide molding, dip casting, dip forming, dip blow molding, dip molding, dip coating, doctor blade coating, dose molding, dosing extrusion, dosing molding, double-daylight molding, double-shot molding, draw working, dry-blend molding, elastomer molding, electric operating injection molding, electroforming, electron-beam polymerization, electroplating, electrostatic spray, embedding, embossing, encapsulation, expandable polystyrene (and other plastics), extruder (different types), extrusion blow molding, extrusion compounding, extrusion molding; female forming, fiber forming, fiber-placement molding, fiber reinforced molding, fiber spinning (wet, dry, jet, etc.), fibrillation, first in, first out injection molding, filament placement, filament winding (different types), film casting, film extrusion, flame spraying, flat film, flexible plunger molding, flocculation, flocking or floc spraying, flow molding, fluidized bed, foamed casting (different types), foamed extrusion, foamed-in-place, foamed-in-place gasketing, foamed molding (many different types such as injection, extrusion, calendering, casting, blow molding, etc.), foamed reservoir molding, forging, forming (different types), forming plastic-metal, forming scrapless, forming solid-phase pressure, foundry molding, fourdrinier, four-station molding, free extrusion, free molding, fusible-core molding, gas-assist molding, gas-assist molding without gas channels, gas blow molding, gas counterpressure injection molding, gas counterpressure molding, gas injection foam molding, gas injection molding, gear-pump extrusion, gear-pump injection molding, geometric forming, geometric molding, glass-fiber spinning, glass-mat reinforced molding, granular paint injection, graphitized fiber spinning, grease-free injection molding, group transfer polymerization, grow molding, hand layup molding, heat-cured rubber molding, heat sealing, high-density molding, high-frequency molding, high-pressure foam molding, high-pressure injection molding, high-pressure molding, horizontal extrusion, horizontal injection molding, horizontal wheel blow molding, horizontal wheel extrusion, horizontal wheel forming, horizontal wheel molding, hot melt molding, hot stamping, hot working, hybrid-electric operating injection molding, hydroclave molding, hydromechanical clamp injection molding, impregnation molding, impulse sealing, infusion molding, injection blow molding, injection compounding, injection-compression molding, injection-die pultrusion, injection molding (different types), injection molding-prepressurized cavity, injection-molding stamping, injection transfer molding, in-line slot extrusion/thermoforming, in-mold coat molding, in-mold decorating, intermediate pressure molding, interpenetrating blend molding, intrinsic molding, inplace molding, insert injection molding, insert molding, intrusion-flow molding, inverse lamination, investment casting, isotactic molding/pressure, jet molding, jet spinning, lagging molding, laminated molding, layup molding, leatherlike molding, lego molding, last in, last out injection molding, liquid crystal extrusion, liquid crystal molding, liquid curing extrusion, liquid injection molding, liquid silicone rubber injection molding, liquid transfer molding, lost-wax molding, low-pressure foam molding, low-pressure injection molding, low-pressure inverted-force injection molding, low-pressure molding, low-profile resin molding, machining, male forming, manifold molding, manual extrusion, manual molding, manual processing, marbleize molding, Marco pressure molding, Marco vacuum molding, Marco vacuum-pressure molding, matched-die molding, mechanical clamping injection molding, melt lamination, melt roll, metal injection molding, metallizing, metal powder injection molding, metal powder molding, metal spraying, microencapsulation, molding with rotation, melt processable rubber process, melt-processable wood process, metal-plastic molding, molding (compression, injection, bag, and so on molding), molecular density molding, multicolor injection molding, multicomponent injection molding, multicompound molding, multiinjection molding, multilayer blow molding, multilayer foam extrusion, multilayer foam-injection molding, multilayer solid-foam extrusion, multilayer solid-foam molding, multilayer solid extrusion, multilayer solid molding, multilive feed molding, multimaterial molding, multistation forming, multistation molding, multiwall molding, netting, netting extrusion, nonporous metal-plastic molding, notched die molding, off-center injection molding, offset extrusion, offset molding, one-shot molding, open molding, orientation process (different types), oriented extrusion, open-frame forming, oriented molding, oscillating die extrusion, overcoat extrusion, overcoat lamination, overcoat molding, packaging (different types), parallel laminating, pelletizing extrusion, perforating, photopolymerization, physical blow molding, pinhole-free coating, pipe blow molding, pipe extrusion, plastic-concrete process, plastic-metal molding, plunger molding, polyurethane foam molding, poromeric molding, postconsumer extrusion, postconsumer molding, postforming, powder molding, potting, powder injection molding, preform molding, premolding, prepolymer molding, prepreg molding (different types), press lamination, pressure bag molding, pressure fabrication, pressure forming, pressure lamination, processing-artistic, processing-basics, profile extrusion, pulforming, pulp molding, pulse molding, pultrusion molding, pyrolysis carbon fiber spinning, ram extrusion, ram injection molding, ram molding, rapid prototype molding, radio-frequency molding, reaction injection molding, reactive polymer processing, recycled compound molding, reinforced foam molding, reinforced plastics (different types), reinforced reaction injection molding, reinforced reaction molding, reinforced rotational molding, resin transfer molding, rock-and-roll molding, roll covering, rolling, roll milling, room-temperature molding, rotary-core molding, rotary molding, rotary-table molding, rotating die extrusion, rotating mold-turret injection molding, rotational casting, rotational molding, rotomold, rotomold ovenless, rotovinyl sheet, rubber insert molding, salt-bath process (different types), sandwich molding, scrapless forming, scrapeless molding, screw molding, screw plunger transfer molding, Scorim molding, scrimp, semiautomatic extrusion, semiautomatic molding, semiautomatic processing, sheet extrusion, sheet-molding compound, sheet-molding compounding continuous fiber molding, sheet-molding compound directionally oriented molding, sheet-molding compound randomly oriented molding, shell molding, shrink wrap, shrink wrap bag processing, shuttle forming, shuttle molding, sintering, skin molding, skiving, sliding insert molding, slip forming, slot extrusion, slush molding, smart-card/closed-loop controlled injection molding, soluble-core injection molding, soluble-core molding, solution casting, solvent bonding, solvent casting, solvent molding, spin casting, spinneret fiber forming, spinning, spline process, spraying (different types), spray-up molding, spread coating, spreader molding, squeeze molding, stack blow molding, stack injection molding, stamping, staple-fiber spinning, steam chamber-filament spinning, stretch blow molding, strip molding, structural casting, structural foam molding, structural-reaction injection molding, stuffer injection molding, supperplastic forming, syntactic foaming, tape placement wrapped molding, tenter frame forming, thermal expansion molding, thermoforming (different types), thermoplastic extrusion, thermoplastic injection molding, thermoplastic molding, thermoplastic structural foam molding, thermoset extrusion, thermoset injection molding, thermoset molding, thermoset structural foam molding, thick compound molding, thin-wall injection molding, thixomolding, three-platen injection molding, three-station molding, toggle clamp injection molding, tooling torpedo molding, transfer molding, trickle impregnation, tube extrusion, tubing-heat shrinkable, turnkey injection molding, twin-sheet forming, twin-sheet thermoforming (different types), two-color injection molding, two-color molding, two-platen clamp injection molding, two-stage injection molding, two-station molding, ultrasonic fabrication, ultrasonic vacuum bag molding, ultraviolet molding, vacuum bag molding, vacuum casting, vacuum coating, vacuum forming, vacuum hot forming, vacuum press molding, vacuum-pressure bag molding, variable-pressure foaming, vented extrusion, vented injection molding, vertical extrusion, vertical injection molding, vertical-wheel extrusion, vertical-wheel forming, vertical-wheel injection molding, vibration gas injection molding, vibration molding, vinyl dispersion, vinyl plastisol forming, viscous molding, void-plastic impregnation, vulcanization, waste molding, welding, wet layup molding, wire coating, wire-coating extrusion, wheel blow molding, wood-plastic impregnation molding, wood-plastic vacuum impregnation casting, wood pulp-plastic injection molding and others. Also called *primary equipment.* See **plastic; plastic material type.**

fabricating startup and shutdown Primary and secondary (auxiliary) equipment manufacturers have startup and shutdown procedures that provide an initial guide. Procedures depend on variables that include type of plastic being processed and available controls. Machine operation takes place in three stages: (1) running a machine and its peripheral equipment; (2) setting processing conditions to a prescribed number of parameters for a specific plastic, with a specific tool (die, mold, etc.), in a specific processing line, to meet product performance requirements; and (3) problem solving and fine tuning the complete line, which leads to meeting performance requirements at the lowest cost. A successful operation requires close attention to many details, such as quality feed materials, flow, and a heat profile adequate to melt but not degrade the plastic. Processors must also become familiar with troubleshooting guides that are available from equipment manufacturers. See **design, plant layout via computer; extruder operation shutdown; extruder operation startup; plastic processing.**

fabricating time Reducing fabricating time reduces cost when the process controls for the equipment and material being used are properly set up. See **FALLO approach; molding area diagram; molding volume diagram; process control.**

fabricating turnkey operation A complete fabrication line or system, such as an extruder line with upstream and downstream equipment. Controls interface all the equipment in-line from material delivery to the end of the line handling the product for in-plant storage or shipment out of the plant. See **auxiliary equipment; fabricating process type.**

fabricating variable Equipment and material variables that are controllable. See **design and tolerance analysis.**

fabricating, world-class Competitiveness built around customer needs should be the primary focus of a distribution or manufacturing strategy. The best approach identifies opportunities to improve effectiveness and reduce the costs of the manufacturing and distribution systems, both of which will benefit the customer and, thus, the manufacturer. One opportunity is to consolidate distribution centers worldwide. Another opportunity is to adopt a world-class manufacturing approach to fabricating processes. New philosophies and methodologies such as just-in-time fabricating to total quality management can be applied to cut operating costs and improve quality levels, customer service, and return on manageable assets. See **American Standards for Testing Materials; entrepreneur; quality level, acceptable; ISO-9000 certification; legal matter: agreement not to compete; plastic competition; SI; specification and standard limitations.**

fabricator certification See **processor certification.**

fabricator training See **quality; training.**

fabricator training via computer See **process simulator.**

fabric, balanced See **directional property, balanced.**

fabric, basket-woven Two or more warp fibers that go over and under two or more filing fibers in a repeat pattern. This weave is less stable than the plain weave but produces a flatter and stronger fabric. It is also a more pliable fabric and will conform more readily to simple contours. It maintains a certain degree of porosity without losing too much firmness but is less firm than the plain weave.

fabric, bias-woven Warp and fill fibers that are at an angle to the length of the fabric.

fabric batt See **felt.**

fabric bias Fabric consisting of warp and fill fibers at an angle to the length of the fabric.

fabric, bias cut Cutting material at 45° from the weave pattern.

fabric bonded A web of fibers held together by an adhesive medium, which does not form a continuous film. See **fabric, nonwoven.**

fabric, broadgood Fiber woven usually 50 in. (1.27 mm) wide. It may or may not be impregnated with plastic and is usually furnished in rolls of 50 to 300 lb (25 to 140 kg). See **impregnation.**

fabric, burlap A coarse, loose woven fabric made from jute or similar fiber. Used in low-cost, low-performance laminated or reinforced plastics. See **fiber, jute; laminate; reinforced plastic.**

fabric, canvas A closely woven cloth of flax, hemp, or cotton that is sometimes used in industrial laminated plastics. It usually represents fabric weighing more than 4 oz/ yd^2 (0.14 kg/m^2). See **fiber, flax.**

fabric coating See **coating, fabric.**

fabric count In fabric, it is the number (count units) of warp fibers (ends) and filling fibers (picks) per unit of length (cm or in). See **fiber denier; tex; yarn count.**

fabric, cowoven A fabric woven with two different types of fibers in individual yarns. For example, thermoplastic fibers woven side by side with glass fibers.

fabric crimp Cloth woven with about equal corrugations in both the warp and fill. See **crimp.**

fabric, crowfoot A three-by-one weave—that is, a filling thread floats over three warp threads and then under one. One side of this fabric looks different than the other. Fabrics with this weave are popular since they are more pliable than either the plain or basket weave. They are easier to form around curves and provide three-dimensional forming.

fabric desizing The process of eliminating sizing, which is generally starch, from gray goods prior to applying special finishes or bleaches for fibers such as glass or cotton. See **fiberglass binder/sizing coupling agent.**

fabric distortion See **distortion.**

fabric drape The ability of a fabric weave to conform to a contoured surface.

fabric, eight-harness satin A seven-by-one weave in which a filling thread floats over seven warp threads and then under one. Like a crowfoot weave, one side looks different than the other side. This weave is more pliable than others and is especially adaptable to forming around the more complex shapes.

fabric, elastic A fabric that is made from an elastomer either alone or in combination with other textile materials. At room temperature it will stretch under tension and will return quickly to its original dimensions and shape when tension is removed. See **elastomer; elongation.**

fabric fill See **yarn fill.**

fabric filler Pieces of chopped cloth or other fabric to improve properties or reduce cost. See **filler.**

fabric fill face The side of a woven fabric on which the greatest number of yarns are perpendicular to the selvage.

fabric finish See **finish.**

fabric, flash-spun See **fabric, nonwoven flash-spun.**

fabric fluted core See **core, fluted.**

fabric, four-harness satin A three-by-one weave. The filling thread floats over three warp threads and then under one thread. The two sides of this fabric have different appearances. As with other satin weaves, it provides some flexibility to form around shapes. Also called *crowfoot satin* because the weaving pattern resembles the imprint of a crow's foot.

fabric, geotextile See **geotextile.**

fabric gigg A machine that raises a nap on fabrics. See **fabric nap.**

fabric gout Foreign matter, usually lint or waste fibers, that is woven into a fabric by accident. See **contamination.**

fabric, gray It is any fabric, yarn, or fiber before finishing, sizing, dyeing, and so on. Also called *greige goods*. See **fiber finish; fiberglass binder/sizing coupling agent; goods.**

fabric hand The softness of fabric as determined by touch and subject to personal judgment.

fabric, impregnated A fabric in which the interstices between yarns are completely filled with the impregnating compound throughout the thickness of the fabric, as distinguished from sized or coated fabrics where these interstices are not completely filled. See **impregnation.**

fabric, knitted A woven fabric that has an interlacing (interloping) yarn or thread in a series of connecting loops with needles. This is a rather compact woven construction used with plastic to produce decorative film or sheets, reinforced plastics, and so on. See **decorating; fabric, woven; reinforced plastic.**

fabric, laminated See **laminate.**

fabric, leno A locking-type weave in which two or more warp threads cross over each other and interlace with one or more filling threads. It is used primarily to prevent the shifting of fibers in open-weave fabrics.

fabric, mock leno An open weave that resembles a leno. It uses a system of interlacing that draws a group of threads together and leaves a space between one group and the next group. The warp threads do not actually cross each other as in a real leno, and therefore no special attachments are required for the loom. It is used when a high strength is required and the fabric is to remain porous.

fabric, mechanical See **fabric, nonwoven.**

fabric, melt-blown See **fabric, nonwoven melt-blown.**

fabric nap Little lumps of tangled fibers or small thickened places found in fabric or yarn. See **fabric gigg.**

fabric nesting See **reinforced-plastic nesting.**

fabric, nonwoven The textile and paper industries are based on wet and dry processes. Manufacturers of nonwovens for plastics also draw on both. With the wet there are basically two types—namely, the Fourdrinier and cylinder machine types that have been modified. Also two basic types exist for the process—formation of the web and application of the bonding agent or system where mechanical carding of fibers is used. The particular equipment and method of operation to be used, with their many modifications, are influenced by requirements such as mechanical properties, softness, surface condition, and tenacity. Certain types of nonwoven fabric are directly formed from short or chopped fiber as well as continuous filaments. They are produced by loosely compressing together fibers, yarns, rovings, and so on with or without a scrim cloth carrier, assembled by mechanical, chemical, thermal, or solvent methods. Products of this type include melted and spun-bonded fabrics. See **fabric, woven; fiber carding.**

fabric, nonwoven flash-spun Flash-spinning is a radical departure from the conventional melt-spinning methods to produce nonwoven fabrics. In flash-spinning a 10 to 15 wt% solution of, for example, HDPE in trichlorofluoromethane or methylene chloride is heated to 200°C (392°F) and pressurized to at least 4,500 kPa (650 psi). This pressurized vessel is connected to a spinneret containing a single hole. When the pressurized solution is permitted to expand rapidly through the single hole, the low-boiling solvent is instantaneously flashed off, leaving a three-dimensional film-fibril nonwoven network referred to as a *plexifilament.* This process with precise conditioning can result in a film thickness of 4 µm.

fabric, nonwoven mechanical The general paper product processed through fourdrinier cylinder wet machines is very dense, so the saturation with plastics is very difficult. Saturability is improved by reducing paper thickness, including plastics in the pulp mix, using foaming or dispensing agents in the pulp, air-blowing paper during drying, or increasing hole diameters or porosity in wire screen or felt carriers used in the processing. In the dry process, sheets are formed by mechanical carding of fibers, air-laying system, or air-flotation system. The techniques provide latitude in orientation of fibers, including continuous-swirl fiber patterns, fibers roughly parallel in the machine direction, or other patterns such as orthotropic and isotropic lay-ups. See **fiber carding; fourdrinier; paper; yarn, carded.**

fabric, nonwoven melt-blown A fabric that is composed of discontinuous filaments and is smaller than those of spun-bonded fabrics. Fibers are very fine with a typical diameter of 3 µm. Most commercial products are made of polyester or high melt-flow polypropylene plastic.

fabric, nonwoven spun A fabric that includes spun-bonded, flash-spun, melt-blown, or mechanical nonwoven swirl. They are used in durable and disposable products that include interlining-interfacing (apparel), carpet backing, geotextile, roofing, industrial filtration media, surgical apparel, medical dressing, and diaper.

fabric, nonwoven spun-bonded A fabric that is distinguished from other nonwoven fabrics by a one-step operation that provides a complete chemical to fabric route. The process integrates the spinning, lay-down, consolidation, and bonding of continuous filaments to form fabrics. Its largest growth area is disposable diaper-cover stock. See **plastic paper; Tyvek.**

fabric pattern See **fabric, woven.**

fabric, pick count for An individual filling yarn running the width of a woven fabric at right angles to the warp. The call out is the number of filling yarns per inch (cm) of woven fabric. Also called *woof* or *weft count.*

fabric, plain A one-by-one weave where one filling thread floats over one warp thread, providing bidirectional strength properties.

fabric ply See **blanket.**

fabric prepreg See **reinforced-plastic prepreg.**

fabric roll See **roll.**

fabric, satin A fabric woven to appear smooth and glossy on the face and dull on the back. Various satin patterns are used. See **fabric, woven eight-harness satin; fabric woven, four-harness satin.**

fabric scrim **1.** A low-cost reinforcing nonwoven fabric made from continuous filament yarn in an open-mesh construction. Its uses include surfacing reinforced plastics to produce a smooth surface. See **reinforced plastic.** **2.** A scrim that is used as a carrier of adhesives for use in secondary bonding. See **adhesive.**

fabric selvage The edge of a woven fabric that runs parallel to the direction of the warp threads.

fabric, sheer A fabric that is transparently thin or diaphanous. Its uses include serving as an overlayer for plastic protection or providing decorative effects.

fabric, shuttle-mark A fine filling line caused by damage to a group of warp yarns by weaving shuttle abrasion.

fabric surface waviness See **plastic, low-profile.**

fabric, tire-cord See **weftless.**

fabric, twill A basic weave characterized by a diagonal rib or twill line. Each end floats over at least two consecutive picks, allowing a greater number of yarns per unit area than in a plain weave, while not losing a great deal of fabric stability. This pattern has better drapability than either plain or basket weaves.

fabric, vinyl-coated See **vinyl seagoing bag.**

fabric warp See **yarn warp.**

fabric warp face The fabric side that has the greatest number of yarns that are parallel to the selvage.

fabric weave The particular manner in which a fabric is formed by interlacing yarns.

fabric weft See **weft.**

fabric, woven A material that is constructed by interlacing fibers, yarns, or filaments to form such fabric patterns as basket, plain, harness, satin, leno weaves, and scrim. These different weaving patterns are used to provide different processing and directional properties. Their filling threads represent threads in the so-called machine direction; warp threads represent those in the transverse direction or at 90° to the filling thread. See **fabric, nonwoven.**

factice A vulcanizable natural elastomer that is derived from unsaturated vegetable or fish oils and is used in the compounding of other elastomers. See **elastomer; softener; vulcanization.**

factor of ignorance A term that is sometimes used instead of *safety factor.* See **design safety factor.**

fadeometer See **color fadeometer.**

fading resistance See **light resistance.**

Fahrenheit (F) A temperature scale that is related to the Centigrade (C) scale as follows: $F = \frac{9}{5}C + 32$ or $C = \frac{5}{9}(F - 32)$. The temperature of boiling water at sea level or 760 mm H_g is 212°F (100°C). Freezing point of water is 32°F (0°C). See **temperature.**

failure See **adhesive cohesive failure; brittle failure; DART software; ductility; design-failure theory; design-failure theory, Griffith; design safety factor; failure, fault-tree analysis of; fractures; medi-**

cal connectors, female luer failure in; Mohr envelope; plastic advantages and disadvantages; plastic failure or success; plastic product failure; problems and solutions, quality system regulation; tear failure; thermal aging, relative zero defect; thermal index.

failure, catastrophic Failure of an unpredictable nature.

failure, cohesive A rupture occurring entirely within any single uniform layer of an assembly.

failure, dished A symmetrical distortion of a flat or curved section so that, as normally viewed, it appears concave or more concave than desired.

failure, domed A symmetrical distortion of a flat or curved section of a plastic part so that, as normally viewed, it appears convex or more convex than intended. See **distortion.**

failure, fault-tree analysis of (FTA) The procedure that analyzes the individual components of a product and shows how failures could affect its function. See **problems and solutions; zero defect.**

failure time The time that a test specimen fails during a test or that a product in service fails. This time period should be compared to what was expected.

FALLO approach Follow ALL Opportunities. The FALLO approach coordinates the many steps that are involved in processing. Basically the FALLO approach diagram consists of (1) designing a product to meet performance and manufacturing requirements at the lowest cost; (2) specifying the proper plastic materials that meet product performance requirements after being processed; (3) specifying the complete equipment line by (a) designing the tool (mold, die) around the product, (b) putting the properly performing fabricating process around the tool, (c) setting up auxiliary equipment (upstream to downstream) to match the operation of the complete line, and (d) setting up the required complete controls (such as testing, quality control, troubleshooting, maintenance, data recording, etc.) to produce zero defects; and (4) purchasing and properly warehousing plastic materials. Using this type of approach maximizes a product's profitability. See **injection-molding operation optimization; manufacturing execution system; plastic consumption; plastic industry size; processing; productivity; profit and technology; testing and quality control; troubleshooting; World of Plastics Reviews: The Plastics Industry; World of Plastics Reviews: Basics and Overviews of Fabricating processes.**

fallout See **radiation.**

false-body See **viscosity, apparent.**

Farad See **electrical capacitance.**

Faraday's law See **electricity, Faraday's law of.**

farmer and waste See **waste.**

fascia See **automobile bumper fascia.**

fastener A device that joins. Plastic fasteners must meet various performance requirements, such as coefficient of thermal expansion and sustained loads. See **adhesive; automobile, composite; design disassembly; insert; joining; Velcro strip; welding.**

fastener, mechanical A device that joins materials. Mechanical fasteners include machine screws, self-tapping screws, inserts, molded-in threads, rivets, press or interference fits, staking, and nuts and bolts. Fasteners also can be molded in plastic interlocking configurations, such as in snap-fits. A popular method is the insert that is internally threaded to accept a machine screw; knurls and grooves on the outer surface of the insert provide pull-out and rotation resistance. A molded insert should have just sufficient stress around the plastics to avoid the overstressing that can cause self-destruction. See **automobile, composite; insert molding; joining; test, bearing-strength; Velcro strip; welding.**

fastener, nonmechanical A traditional hook-and-loop fastener. It offers strength and reclosability but can also generate particles. Certain plastics, such as urethane acrylate, exhibit a molecular attraction to themselves. This 3M-type nonmechanical fastener provides a user friendly and powerful bonding action. It can reopen and reclose at least 50 times. See **adhesive, mechanical; automobile, composite; molecular arrangement structure; polarity.**

fastener, wet-installation See **joining, wet-installation.**

fatigue The action that causes a failure or deterioration in mechanical properties after repeated, cyclic applications of stress. Test data provide information on the ability of a material to resist the developments of cracks, which eventually bring about failure as a result of long periods of cyclic loading. See **design spring.**

fatigue, constant-amplitude loading A loading in which all the peak loads are equal and all the valley loads are equal.

fatigue, corrosion The synergistic effect of fatigue and aggressive environment acting simultaneously, which leads to a degradation in fatigue behavior.

fatigue crack A crack that develops and extends (propagates) during the cycling and that eventually causes failure of the part. See **test, crack-growth-resistance.**

fatigue cyclic load The number of cycles endured under a load.

fatigue ductility The ability of a material to deform in a ductile manner (elastic behavior) prior to failure or fracture that is determined from a constant-strain amplitude, low-cycle fatigue test. It usually is expressed in direct analogy with elongation and reduction of area ductility measures. See **ductility.**

fatigue ductility exponent The slope of a log-log plot of the strain range and the fatigue life. Data can provide information extending from one to at least 100 years.

fatigue, dynamic The deterioration of a material by repeated deformation. See **dynamic fatigue.**

fatigue endurance limit A measure of load-carrying ability of a material subjected to infinitely repeated fatigue loading or cycling. It is the maximum alternating stress amplitude that can be sustained by a material subjected to a specified mean stress for an infinite number of cycles without failure. It is obtained from the fatigue S-N diagram.

fatigue hysteretic heating Since plastics are viscoelastic, a large amount of internal friction (temperature increase) can be generated within the plastics during mechanical deformation, as in fatigue. This action involves the accumulation of hysteresis energy that is generated during each loading cycle. See **hysteresis heat build-up.**

fatigue life The number of cycles of deformation that cause failure of a test specimen under a given set of oscillating stress or strain conditions. The type of failure provides useful technical information.

fatigue limit The stress level below which a material can be stressed cyclically for an infinite number of times without failure.

fatigue loading, zero crossing See **mean crossing.**

fatigue notch factor The ratio of the fatigue strength with no stress concentrator to the fatigue strength of a similar specimen with a stress concentrator.

fatigue ratio The ratio of fatigue strength to tensile strength when the mean stress and alternating stress are specified.

fatigue S-N diagram A plot of stress (S) against the number of cycles (N) to failure in fatigue testing. Also called *fatigue stress-number of cycle diagram or curve.* See **hysteresis diagram; stress-strain curve.**

fatigue, static The failure of a part under continued static load. It is analogous to creep rupture failure but often is the result of aging accelerated by stress.

fatigue strength The maximum, completely reversed stress under which a material will fail after it has experienced the stress for a specific number of cycles. It is obtained from the fatigue S-N diagram. Also called *endurance strength* or *fatigue stress.* See **spalling.**

fatigue strength versus tensile strength The fatigue strength of most thermoplastics is about 20 to 30% of their ultimate tensile strength as determined in the short-term test; it is much higher for thermoset reinforced plastics.

fatigue stress, mean A dynamic fatigue parameter that is the algebraic mean of the maximum and minimum stress in one cycle (pounds per square inch or mega = Pascal). See **mean; spalling.**

fatigue tension See **tension fatigue.**

fatty acid A straight chain or aliphatic monobasic acid that is either saturated or unsaturated and is widely used in compounding.

Fawcett and Gibson See **polymerization history.**

feather edge See **fin.**

feature An individual characteristic of a part, such as a rib, thread, hole, or taper.

feature defect, zero An individual characteristic of a part, such as thread, hole, or taper. See **zero defect.**

feed To move material into processing equipment. See **barrel; blender; material feeding and blending.**

feedback See **control, feedback; motion-control system.**

feedblock See **coextrusion.**

feeder **1.** Auxiliary equipment that provides a controlled flow of materials (powders, pellets, etc.) to or from a processing operation. See **auxiliary equipment; barrel feed housing; material handling. 2.** An electrical transmission line that carries energy to equipment.

feeder accuracy and repeatability See **repeatability.**

feeder/blender See **compacting; material feeding and blending; mill; mixer.**

feeder, crammer A hopper unit that forces plastics into the feed throat of the plasticator.

feeder, gravity A gravimetric feeder or blender has the ability to pinpoint material accuracy despite variations in bulk density. It basically consists of the feeder (including discharge device), scale, and control unit. A separate feeder system is used for blending. Both batch- and continuous-type units are used. See **material feeding and blending gravimetric.**

feeder, vibratory A device that conveys dry materials from storage hoppers to processing equipment by using a tray vibrated by mechanical or electrical pulses. The frequency and amplitude of the vibrations control the rate of material flow.

feeder, volumetric An enclosed chamber that meters a specific volume of materials. Bulk density, particle size, and particle moisture content usually influence the uniformity of the metering capacity. See **material feeding and blending volumetric.**

feed forward control See **control, feed-forward.**

feed hopper A funnel mounted directly on equipment such as a plasticator barrel over the screw feed section to hold a reserve of material. See **hopper feeder.**

feed orifice See **orifice.**

feed output See **fabricating output.**

feed, starve See **material starve feeding; venting feeder.**

feedstock The materials that are generally derived from crude oil or natural gas through a series of chemical processes with only 2 to 3wt% and that are used to produce plastics. Starting materials can also include other materials, such as coal and other ores, wood, furs, cotton, air, and water. See **oil and gas; oil, cracking; ore; petrochemicals; plastic; plastic and feedstock; plastic products, raw material to; polymerization.**

feedstock, limited See **steel resources, limited; oil resources, limited; plastic myth and fact.**

feldspar See **china clay.**

felt A nonwoven compressed fabric, mat, or bat that is prepared from staple fibers without spinning, weaving, or knitting and that is made up of fibers that interlock mechanically. See **fiber mat.**

female cavity See **mold cavity, female.**

fermentation See **decomposition; zymurgy.**

ferris wheel clamp See **clamping platen, rotary.**
ferris wheel mold See **mold, ferris wheel.**
ferrite A multiple compound of ferric oxide with another oxide such as sodium ferrite. Those with trivalent iron are usually magnetic. They are used during the processing of plastics; the oxides are used as plastic fillers. See **filler; magnet.**
ferroelectric A crystalline material such as barium titanate or potassium-sodium tartrate (rochelle salts) that over certain limited temperatures has a natural and inherent deformation (polarization) of electrical fields or electrons associated with atoms and groups in the crystal lattice. It is used in plastic embedded capacitors, transducers, etc. See **embedding; polarity.**
ferromagnetic material A material, such as stainless steel and iron, in which the magnetic moments or dipoles of atoms exhibit a high degree of alignment parallel to each other in the presence of a magnetic field. This alignment is in opposition to the usual tendency of atoms to orient in random directions due to thermal motion. It is used in induction welding. See **iron; welding.**
ferrous, metal See **metal, ferrous.**
festoon A device for the temporary accumulation or storage of material (film, wire, tape, etc.) in different fabricating processes (extrusion, calender, etc.). For example, a catenary device can be downstream of a film calender line where the film is looped between two or more sets of rolls to accumulate an inventory to facilitate the changing of wound rolls of film. During normal running, the roll sets are close together so that the film goes straight through to the winder. See **accumulator.**
festooning oven An oven used to dry, cure, or fuse plastic-coated fabrics with uniform heating.
fiber A filamentary structure of very small cross-sections typically 0.10 to 0.13 mm (0.004 to 0.005 in.) made from various materials that are at least 100 times their diameter. Fibers can be continuous or made up of short or staple fiber lengths. Also called *filament.* See **acrylonitrile; ash content; birefringence; bristle; capillarity; cellulose fiberboard; directional property; fiberglass binder/sizing coupling agent; fiber, nylon; fiber processing; fiber processing, dry-spinning; fiber-processing filtration; flock; ignition loss; plastics, theoretical versus actual values of; reinforced-plastic dry fiber; reinforced-plastic ignition loss; reinforced-plastic pultrusion fiber bridging; reinforced-plastic weight, areal; test, nondestructive ultrasonic; twist, direction of yarn; vulcanized fiber fish paper.**
fiber, abaca The 6 to 12 ft (1.8 to 3.6 m) long fiber bundles that are produced from the abaca tree and are used in the manufacture of ropes, cables, and reinforced plastics. See **reinforced plastic.**
fiber, acrylic A filament that is made from any long-chain synthetic plastic containing 85wt% or more acrylonitrile. See **acrylic plastic.**
fiber, alumina-silica An amorphous structure with excellent resistance to all chemicals except hydrochloric acid, phosphoric acid, and concentrated alkalies. Its tensile strength is 400,000 psi (2000 MPa), modulus of elasticity is 16 million psi (110 GPa), and upper temperature limit in oxidizing atmosphere is 1470°F (800°C); it is noncombustible, has low heat conductivity, and has thermal shock resistance.
fiber attenuation The process for making thin or slender fibers. It applies to the formation of fiber from molten glass. See **fiberglass.**
fiber biconstituent **1.** A hybrid or composite fiber comprising a dispersion of fibrils of one synthetic plastic within and parallel to the longitudinal axis of another. **2.** A construction of plastic and metal or alloy filaments.
fiber bobbin The smallest production unit of yarn or roving, including its appropriate (usually cardboard or plastic tube) support. Also called *package.*
fiber, boron A fiber that is produced by chemical vapor deposition from a gaseous mixture of hydrogen (H_2) and boron trichloride (BCl_3) on primarily an electrically heated tungsten substrate of 0.5 mil (12.5 μm) diameter. The final filament diameter is 4 mil (100 μm), 5.6 mil (140 μm), or 8 mil (200 μm) in descending order of production quantities; however, both small and large diameters have been produced in experimental quantities. It has exceptionally high tensile strength and modulus of elasticity with a relatively low density. Its upper temperature limit in an oxidizing atmosphere is 250°C (480°F). This high-cost material usually has a matrix of expensive high-performance epoxy plastic. This was the first of the high-strength, high-modulus fibers to be produced. The U.S. Air Force Materials Laboratory, Dayton, OH, was influential in its development in the early 1950s. Its use includes aerospace structural parts, tennis rackets, fishing rods, and golf clubs. See **boron; chemical vapor deposition; fiber, silicon carbide; reinforcement.**
fiber, braided A fiber that has been woven into a tubular shape. See **reinforced-plastic pultrusion braiding.**
fiber breakout A fiber separation or break on surface plies at drilled or machine edges.
fiber bundle A collection of essentially parallel fibers or filaments.
fiber, buttress A type of thread used for transmitting power in only one direction. It has the efficiency of the square thread and the strength of the V-thread.
fiber, carbon (CF) The predominant high-strength, high-modulus fiber that is used in the manufacture of advanced reinforced-plastic composite products. It can be made by the pyrolytic degradation of a fibrous organic precursor. Most CFs are obtained by the pyrolysis of polyacrylonitrile (PAN); this old technology subjects the PAN to temperatures up to 1080°F (2000°C). Other methods include pyrolysis of cellulose (rayon) and acrylic fibers, burning-off binder from the pitch precursor, and growing single crystals (whiskers) via thermal cracking of hydrocarbon gas. CFs are essentially crystalline carbon (graphite)

having high mechanical and physical performances in reinforcements. Their benefits also extend to high thermal stability, electrical conductivity, chemical resistance wear resistance, and relatively low weight. See **chemical vapor deposition; fiber, graphite and carbon characteristic; pitch; test, nondestructive carbon fiber reinforced plastic x-ray scanning.**

fiber, carbon stabilization During forming, the process that is used to render the carbon fiber precursor infusible prior to carbonization.

fiber carding A process of untangling and partially straightening fibers, such as asbestos, by passing them between two closely spaced surfaces that are moving at different speeds, at least one of which is covered with sharp points. The machine converts a tangled mass of fibers to a filmy web. Its use includes reinforcements in reinforcing plastics. See **asbestos; fabric, nonwoven; fabric, nonwoven mechanical; fourdrinier; paper; reinforcement; yarn, carded; yarn, combed.**

fiber, cellulose acetate See **cellulose acetate fiber; cellulose acetate plastic acetate process.**

fiber, ceramic A fiber that consists of approximately 50wt% alumina and 50wt% silica with traces of other inorganic materials. It possesses unique wear and corrosion resistance and high temperature stability. The fibers are made by atomizing a molten ceramic stream using high-pressure air or spinning wheels, chemical vapor deposition, melt drawing, or special extrusion processes. Although glass fibers are also ceramic material, they are not generally categorized as ceramic fiber but are called *glass fibers*. See **fiberglass.**

fiber combing Lining up fibers. See **fiber carding.**

fiber count The number of warp fiber or yarn (ends) and filling fiber or yarn (picks) per inch. The cross-section or thickness of fiber, yarn, or roving is expressed as *denier* or *decitex*. See **yarn construction number.**

fiber creel A spool, along with its supporting structure, that holds the required number of fibers or roving balls for supply packages in a desired position for unwinding into the next processing step such as weaving, braiding, filament winding, and so on.

fiber crimp The waviness of a fiber or fabric that is responsible for void formations. Crimp determines the capacity of fibers to cohere under light pressure. It is measured either by the number of crimps, waves per unit length, or the percent increase in extent of the fiber on removal of the crimp.

fiber cutting or crushing See **filament-winding loop-strength tenacity.**

fiber decitex The fineness (and conversely the cross-sectional area) of a filament, yarn, or rope. It is defined as the weight in g of 10,000 m of the material. One decitex = 0.9 denier. Also called *dtex* or *(deci)tex*. See **fiber denier.**

fiber, definition of *Fiber* refers to filamentary materials and often is used synonymously with *filament, monofilament, whisker*, and *yarn*. It is any material in a form such that it has a minimum length of at least 100 times its diameter. Diameters are usually 0.004 to 0.005 in. (0.10 to 0.13 mm). Fibers can be continuous or reduced to short lengths (discontinuous) where the industry lists less than a specific length, such as 0.125 in. (3.2 mm). A filament is the smallest unit of a fibrous material and usually not used alone. It is the basic unit that is formed during manufacture and gathered into strands of fiber. Their diameters are less than 0.001 in. (0.025 mm). The fineness of a fiber is also identified by its denier.

fiber denier A unit of weight that expresses the size or coarseness but particularly the fineness of a continuous fiber or yarn. The weight in grams of 9000 m (30,000 ft) is one denier. The lower the denier, the finer the fiber or yarn. One denier equals about 40 micron. Sheer women's hosiery usually runs 10 to 15 denier. Commercial work 12 to 15 denier fiber is generated. See **fiber decitex; fiber definition; fiber spinneret; tex.**

fiber desizing **1.** The process of eliminating sizing from gray or greige goods before applying special finishes or bleaches. **2.** The process of removing lubricant size following the weaving of a cloth. See **fiberglass binder/sizing coupling agent.**

fiber drawing A fiber that has a certain amount of orientation imparted by the drawing process when the fibers are formed. It results in a significant increase in strength and other properties. See **fiber processing; orientation.**

fiber end **1.** An individual fiber, thread, roving, yarn, or cord. **2.** In fabric, a warp yarn that runs the length of the fabric. **3.** A strand of roving that consists of a given number of filaments gathered together. The group of filaments is considered an end or strand prior to twisting. **4.** The review on a strand roving (No. **3.**) becomes a yarn after twist has been applied.

fiber fabrication See **fiber processing.**

fiber, felt A fibrous material that is made up of interlocking fibers by mechanical or chemical action, moisture, or heat. Felt can be made of many different fibers, including asbestos, cotton, glass, and nylon. See **felt.**

fiber fibrillation The production of fiber from film. See **fiber processing, spinning.**

fiber finish The surface treatment that is applied to processed fibers, particularly glass fibers. See **fiberglass binder/sizing coupling agent.**

fiber finish, satin A type of finish that has a satin or velvety appearance that is midway glossy (or bright) and mat. It behaves as a diffuse reflector that is lustrous but not mirrorlike.

fiber, flax A natural fiber that is obtained from the inner bark of the flax plant. Its uses include as filler and in producing high-strength reinforced or laminated plastics. See **fabric, canvas; linseed oil.**

fiber float A warp or filling fiber that lies on top of the opposite series of yarn for a distance of several fibers.

fiber fuzz An accumulation of short, broken filaments after strands, yarns, or rovings are passed over a contact point.

fiberglass Glass fibers represent the major material used in reinforced plastics. They are a family of short (staple, chopped, milled) or continuous fiber reinforcement, used widely with both thermosets and thermoplastics for increased strength, dimensional stability, thermal stability, corrosion resistance, dielectric properties, and so on. They are available in different forms, such as mat, fabric, and roving. The fibers are made by the melt drawing of various grades (electrical, chemical, high tensile strength, etc.) of glass and are comprised of strands of filaments (rovings) that can be further processed by size reduction, twisting, or weaving into fabrics or mats. They are often surface modified with coupling agents to improve bonding with plastic matrix or fabric scrim; fabric, woven; fiber fuzz; fiber mat; fiber optic; or to impart special properties, such as electrical conductivity (by coating with nickel). See **glass; interphase; reinforced plastic; reinforced-plastic fiber content; reinforcement; roving; screw-wear.**

fiberglass, bare Glass fiber from which the sizing or finish has been removed. It is also the glass fibers prior to the application of sizing or finishing. See **fiberglass binder/sizing coupling agent.**

fiberglass, bilobe The fiber of nonround cross-section that are prepared by different methods in various geometries. The shapes provides a different fiber packing.

fiberglass binder/sizing coupling agent A substance that is used on different types of fibers to meet their specific requirements, such as bonding capabilities and protection of fibers. A major requirement for these agents involves treating glass fibers. Continuous glass fiber (as well as other fiber) strands that are intended for weaving are treated at their forming bushing during their manufacture with starch-oil binders. These binders protect the fibers from damage by lubrication during their formation and such subsequent textile operations as twisting, plying, and weaving. Usually they are satisfactory when used with thermoplastics but are not compatible with thermoset plastics. The hydrophilic character of the binders allows moisture to penetrate the glass-plastic interface, which leads to degradation of TS-RPs in wet and humid environments. Binder is removed via heat treatment before being used with these plastics. This is accomplished by exposing the reinforcing material (fabric, etc.) to carefully controlled time-temperature cycles. To protect the weak heat-cleaned fibers, chemical sizing coupling agents are used, such as methacrylic chromic chloride complex, and organosilanes. See **additive, liquid; ash content; binder; fabric desizing; fiber desizing; fiber processing; hydrophilic surface; ignition loss; reinforced-plastic ignition loss; silane coupling agent; titanate coupling agent.**

fiberglass bushing The spinneret platinum unit through which molten glass is drawn in making glass filament. See **fiber spinneret.**

fiberglass, cheese A supply of glass fiber wound into a cylindrical mass.

fiberglass, chopped Fiberglass is cut from lengths of fibers or produced into short fibers. Their length can range from milled to any short length with the usual about 3/4 in. as well as up to 2 in.

fiberglass chopper A device—such as a chopper gun, long cutter, or roving cutter—that cuts glass fibers into strands and shorter fibers to be used as reinforcements in preforms and spray. See **cutter.**

fiberglass, continuous A strand of filaments (rovings) that can be twisted and used alone or in many different configurations to reinforce plastics and elastomers. Also called *long glass fiber, continuous-strand roving, continuous roving*, or *continuous glass roving.*

fiberglass devitrification The formation of crystals (seeds) in a glass melt, usually occurring when the melt is too cold. These crystals can appear as defects in glass fibers.

fiberglass diameter The standard in the reinforced-plastics industry uses letter designations that range from about 1.5 to 5.1×10^{-4} in. (3.8 to 13 μm).

fiberglass forming package A single glass strand that is gathered on a thin-wall paper or plastic tube to be used in manufacture.

fiberglass marble A small sphere of glass that is used for melting and subsequently drawing into glass fibers.

fiberglass, milled A fiber that is made by hammer milling continuous glass ends into very short fibers such as 1/64 to 1/4 in. (0.40 to 6.35 mm). It is used as anticrazing reinforcing fillers for plastics and adhesives. Also called *milled glass filler.* See **hammer; mill.**

fiberglass production Both continuous and staple fibers are manufactured by the same basic process up until fiber drawing. The temperature of glass melt and actual production method vary depending on glass composition. Generally, about 1,260°C (2,300°F) is used with melts extruding through platinum multiopening bushings (spinnerets). Two principal manufacturing processes are used—the glass-marble (batch) method or the direct-melt method. See **attenuation; fiber processing.**

fiberglass slug A glass-fiber imperfection that is a particle of glass that sometimes takes the form of a glass bead.

fiberglass texturizing For special applications, fibers are subjected to a jet of air impinging on their surfaces, which causes random controlled breakage or fluffing of their surfaces. Although mechanical damage occurs that weakens the fibers, its bulkiness allows greater plastic absorption. See **texturizing.**

fiberglass type Several types are used: E-type is most frequently used (in at least 80wt% of all the glass fiber used in reinforced plastics) and is suitable for electrical grades (borosilicate type); it is also called *electric glass.* C-type is used for chemical stability. D-type is used for precise controlled dielectric constant (high boron content). M-type is used for high modulus of elasticity (high berlia content). R-type is a cross between E- and S-types with limited production. S-type is used for high tensile strength (magnesia-alumina-silicate content). See **fiber, ceramic; glass composition; yarn designation.**

fiber, graphite A fiber that is made from a pitch or polyacrylonitrile (PAN) precursor by an oxidation carbonization and graphitization process that provides a graphitic (crystalline form of carbon) structure. See **fiber, carbon; graphitization; pitch; stabilization.**

fiber, graphite and carbon characteristic The terms are often used interchangeably, though they differ. The basic differences lie in the temperature at which the fibers are made and heat treated, in the amount of elemental carbon produced, and mechanical properties. Graphite fibers are graphitized at 1,900 to 2,480°C (3,450 to 4,500°F) and assay at more than 99% elemental carbon. The carbon fibers typically are carbonized in the region of 1,315°C (2,400°F) and assay at 93 to 95% carbons. See **reinforcement.**

fiber, heat-cleaned See **fiberglass binder/sizing coupling agent.**

fiber, hollow A plastic fiber that can produce high-bulk, low-density fabrics. Other fiber configurations can be produced, such as trilobal cross-section. Annular dies are used to produce the desired hollow cross-section shape. Fiber spinning methods used are (1) wet from a plastic solution into a liquid coagulant, (2) dry from a plastic solution in a volatile solvent with an evaporative column, and (3) conventional melt systems.

fiber, inorganic A fiber that includes glass (different types), aluminum silicate, beryllium glass, carbon, ceramic, graphite, and quartz (fused silica). See **fiberglass type.**

fiber, jute A bast fiber obtained from the stems of several species of the plant corchorus found mainly in India and Pakistan. Used as a filler for plastic compounds and for over a half century as a reinforcement with thermoset plastics for the fabrication of reinforced plastics. See **fabric, burlap.**

fiber, Kevlar See **fiber, nylon.**

fiber kink See **kink.**

fiber lay See **filament lay.**

fiber length, critical The minimum fiber length required for shear loading to its ultimate strength by the matrix.

fiber linter A short, fuzzy fiber that adheres to the cotton seed after ginning. It is used in rayon manufacture, as fillers for plastics, and as a base for the manufacture of cellulosic plastics. See **cellulose; lint.**

fiber mat A fibrous material that is used in reinforced plastics and consists of randomly and uniformly oriented (1) chopped fibers with or without carrier fibers or binder plastics, (2) short fibers with or without a carrier fabric, (3) swirled filaments loosely held together with a plastic binder, (4) chopped or short fiber with long fibers included in any desired pattern to provide additional mechanical properties in specific directions, and so on. Fiber mat is produced in flat and curved blanket sheets and tape forms for use in the different reinforced-plastic processes. See **felt; veil.**

fiber mat, needled A mat that is felted together in a needle loom with or without a carrier.

fiber mat veil An ultrathin mat similar to a surface mat that is often composed of organic fibers as well as glass fibers.

fiber material, plastic To produce fibers, the most important materials are polypropylene, nylon 66, polyester, and PETP; other plastics are also used. Each plastic family has different grades to provide different properties during and after being processed. Their plastic fiber structures have different levels of molecular organizations, with each relating to certain aspects of fiber behaviors and properties. As an example, their organochemical structure defines the chemical composition and molecular structure. This molecular structure is directly related to the fibers chemical properties, dye ability, moisture sorption, and swelling characteristics and indirectly related to all physical properties. The physical properties of fibers are influenced by the processing techniques, which are affected by factors from melt conditions to windup speed. However, they are strongly influenced by the plastic morphology. All plastic fibers that are useful in textile applications are usually semicrystalline and in an irreversible oriented pattern. See **fiber processing; molecular structure.**

fiber, metallic A manufactured fiber that is used in reinforced plastics and is composed of metal, plastic-coated metal, metal-coated plastic, or a core completely covered by metal. Examples include steel, aluminum, magnesium, and tungsten. See **reinforcement, whisker; whisker, metallic.**

fiber, micro- A fiber whose individual filaments are less than 1.0 denier or 1.0 tex. It is four times finer than the average human hair; at least three times finer than cotton fiber; and finer than natural silk. Microfibers are thermoplastic polyester plastic spun and oriented for lightweight durability, and water resistant materials. See **fiber denier; tex.**

fiber, milled See **fiberglass, milled.**

fiber, nylon The generic name for the organic aromatic polyamide fibers. It has a long chain of synthetic polyamides (nylon) in which over 85wt% of the amide linkages are attached directly to two aromatic rings. DuPont's trade name for it is Kevlar. It has excellent properties such as high strength, modulus of elasticity, lightweight, impact resistance, creep-rupture characteristics, and chemical and mechanical stability over a wide temperature range. It is used in reinforced plastics, high-performance fabrics (boat sails, bulletproof vests, etc.), and medical devices. Also called *aramid fiber.* See **fiber processing, gel-spinning; Kevlar; safety, police-officer; polymerization initiator; reinforced plastic.**

fiber, one-ended A fiber so short in length that it appears to have only one end. Examples include very short-length milled glass fibers and asbestos fibers.

fiber optic The guidance of electromagnetic radiation along transparent dielectric hair-thin glass fibers. The guidance usually involves a mechanism known as *total internal reflection.* If the fibers are of dimensions comparable to the wavelength of light, the fiber will act as a wave guide to conduct the radiation in discrete modes. Glass fibers with extruded plastic coating, usually PE, are used. A fine-drawn silica (glass) fiber or filament of exceptional purity and specific optical properties (refractive index) is used to transmit laser light impulses almost instantaneously and with high fidelity. See **extruder wire coating, optical-fiber; light index of refraction; thermoset plastic curing, fiber-optic sensor.**

fiber orientation The alignment of fiber reinforcement within the part that affects mechanical properties. The properties usually increase in the direction of alignment but are reduced perpendicular to alignment. See **directional property.**

fiber pattern The pattern formed by the fibrous strands. See **fabric, woven.**

fiber pencil A rodlike assemblage of fibers that is in close packed parallel orientation of generally uniform diameter and that can be fiberized readily.

fiber pick An individual filling yarn that runs the width of a woven fabric at right angles to the warp. Also called *fill, woof,* or *weft.*

fiber, polybenzimidazole See **polybenzimidazole plastic.**

fiber, polyethylene See **fiber processing, solution-spinning; Spectra.**

fiber, polyethylene terephthalate See **reinforced plastic, XTC.**

fiber processing Thermoplastic fibers or filaments are produced by screw extruders that use the three common methods of melt spinning, dry spinning, and wet spinning. There are many variations and combinations of these basic processes. Other types of fiber-forming processes include (1) reaction spinning, (2) dispersion, emulsion, and suspension spinning, (3) fusion-melt spinning, (4) phase-separation spinning, and (5) gel spinning. The processes basically force molten plastic by an extruder or gear pump through fine holes in a spinneret or spinnaret (die). In turn, it is immediately stretched or drawn (oriented), cooled, and collected at the end of the line. During this process it may be subjected to other operations, such as (1) thermal setting and thermal relaxation processes to provide dimensional stability, (2) twisting and interlacing to provide cohesion of the filaments with or without sizings, (3) texturing, and (4) crimping and cutting to provide staple products. The speeds of certain lines using the melt and dry spinning processes can go from 6,600 to 13,000 ft/min (2,000 to 4,000 m/min). See **cupric oxide; extrude; fiber; fiber spinneret; filament; gear pump; roving; yarn.**

Numerous techniques for producing fibers without using the spinneret have been used. They include centrifugal spinning, electrostatic spinning, tack spinning, and solid-state extrusion. The SSE process extrudes through a capillary rheometer with a conical die; the processing temperature is close to the melting point of the plastic. See **fiber processing, solid-state extrusion.**

In the manufacture of fibers, a relatively isotropic plastic with properties similar in all directions converts into an orthotropic plastic where most of the plastics strength is in the direction of the fiber axis. This desirable effect provides a certain degree of fiber strength in the longitudinal direction but usually not enough. So the fibers are made stronger by stretch-orientation during or after processing. These spinning lines can include a variety of operations that are useful for the fibers' different applications. A finish can be applied after cooling in-line. Rather than keeping them straight, texturing techniques are used. Texturing introduces crimp, whereby the straight filaments are given a twisted, coiled, or randomly kinked structure. A yarn that is made up of these filaments is softer and more open in structure; it is more pleasing to the touch. Finishes are used to improve the processing and handling of fibers. The finishing mix can include a lubricant. See **fabric, nonwoven; fabric, woven; fiberglass binder/sizing coupling agent; directional property; kink.**

fiber-processing development Unusual plastic fibers such as polyolefin fibers are produced by a spurted or melt-blown spinning technique. A variety of directly formed nonwovens with excellent filtration characteristics are produced. The original development was by Exxon Corp., which produced very fine, submicrometer filaments. Pulplike olefin fibers are produced by a high-pressure spurting process that was developed by Hercules, Inc. and Solvay, Inc. A high-modulus commercial polyethylene fiber with properties approaching those of aramid and graphite fibers is prepared by gel spinning. Higher tensile strengths are also available from gel spinning or fibrillar crystal growth. See **plastics, theoretical versus actual values of.**

fiber processing, dry-spinning In dry spinning a plastic solution is extruded (metering pumped) through a spinneret. The filaments exit the spinneret through a gas-heated cabinet where the solvent is rapidly removed from the plastic filaments. The suitable solvent is filtered and recovered for further use in-line. Filaments end up at the driven haul-off roll.

fiber-processing filtration Many processes require a plastic melt that is free of contaminates larger than a specific size. The fiber processors usually filter down to 5 micron particle size to protect the melt-spinning machines from filament breaks. The fiber process typically operates at very high speeds. A filament break at this speed is costly to both the product quality and the process efficiency. The media used for filtration has included sand packs, wire screens, sintered metal-powder sheets, and sintered metal-fiber sheets. There are also different sandwich combinations, such as wire screens and sintered metal-fiber sheets, that in theory provide the best properties of each component. With a gear pump, running clearance can be as low as 0.00025 in. (0.006 mm) about its periphery and on either side of the metering gear. Any slight burr, nick, or particle of any "foreign" matter will cause scoring and possible seizure of the pump. Recognize that 0.001 in. (0.025 mm) equals 25 microns, so filtration down to just the pump has to be down to 6 microns or less. See **contamination; filtration, ultra-; gear pump.**

fiber processing, gel-spinning A method of producing the world's strongest commercial fiber by increasing the polyethylene fiber strength by 30% via gel spinning. The product is 15 times stronger than steel and twice as strong as aramid fiber. It uses ultrahigh-molecular-weight polyethylene (patented by DSM High Performance Fibers, Heerlen, Netherlands). In this process, UHMWPE molecules are dissolved in a volatile solvent. By cooling and solvent removal, a gellike fiber is spun from this solution. It is then subjected to a drawing-orienting operation. In the gellike fiber, the molecules lie folded in crystals that are at right angles to the fiber length. In the drawing process, these molecules are tipped over so they unfold in longitudinal direction, which is what gives the fiber its high strength. See **fiber processing, solution-spinning; modulus of elasticity; molecular structure; molecular weight; orientation; plastics, theoretical versus actual values of; polyethylene plastic, ultrahigh molecular weight; reinforcement; Spectra; tensile strength.**

fiber processing, jet-spinning For most purposes this process is similar to fiber spinning. Hot-gas jet spinning uses a directed blast or jet of hot gas to pull molten plastic from a die lip and extend it into fine fibers.

fiber processing, solid-state extrusion (SSE) A means for the deformation and evaluation of uniaxial molecular chain orientation and product extension for a wide range of plastics. Developments produced HDPE drawn into fibers with some of highest specific tensile moduli and strengths. A two-step drawing process is used for the preparation of polyoxyethylene, polypropylene, and polyethylene fibers. The plastic is first drawn to a natural draw ratio at a fast rate and subsequently slowly superdrawn at a temperature that depends on the crystalline dispersion temperature. A highly oriented extrudate can be obtained by extruding through a capillary rheometer with a conical die at temperatures close to the melting point. Initial work led to the development of transparent and fibrous linear PE extrudates. These were obtained by extruding HDPE from the molten state (270 to 277°F (132 to 136°C)) above a critical shear rate in a capillary rheometer and through a conical die. This procedure was subsequently modified by processing HDPE exclusively in the solid state where the plastic is semicrystalline before extruding through the die. This modification produced continuous transparent fibers with moduli in the range of 4,400 to 10,200 psi (30 to 70 MPa). See **extruder, solid-state.**

fiber processing, spinning The processes principally used are wet spinning, dry spinning, and melt spinning. The plastic and ingredients (such as primarily stabilizers, pigments, and rheological modifiers) are fed into a screw extruder. The gear pump accurately meters melt through a filter pack of graded sand or porous metal and a spinneret. The multihole spinneret represents the die. On leaving the spinneret, the molten filaments pass at very high speed usually vertically downward into water or a countercurrent of air where they are cooled and solidified. At the same time, after leaving the spinneret, they are stretched to the desired diameter. Finish can be applied prior to the fiber reaching the end of the line, where it is wound on bobbins or other windup rolls. To obtain the required high-performance properties, reheating and drawing orient the fibers. This is usually a separate operation since it requires much higher linear speeds than melt spinning.

The slit-film or film-to-fiber technology produces a substantial volume of polypropylene fibers. Cutting or slitting the film produces fibers. Stretching before or after the cutting process orients the fiber. Also used is mechanical or chemomechanical fibrillation. In this procedure film is created to be anisotropic by stretching before fibrillation. This is the phenomenon wherein filament or fiber shows evidence of basic fibrous structure or fibrillar crystalline nature. It occurs by a longitudinal opening up of the filament under rapid load with excessive tensile or shearing stresses. Separate fibrils can then often be seen in the main filament trunk. The whitening of the plastic when unduly strained at room temperature is a manifestation of fibrillation. Applications for this product are primarily for carpet backing, rope, and cordage. See **fiber processing, jet-spinning; orientation; plastics, theoretical versus actual values of.**

fiber processing, solution-spinning A process that is used to produce high-modulus polyethylene fibers. Fibers are called *extended-chain polyethylene* (ECPE). Fibers have tensile strengths of 3.75 to 5.60 × 10^5 psi (2,890 to 3,860 MPa) and moduli of 15 to 30 × 10^6 psi (103 to 207 MPa). In this process a high-molecular-weight PE is used. The process begins with the dissolution in a suitable solvent of a polymer of about 1 to 5 million molecular weight. The solution disentangles the polymer chains, a key step in achieving an extended-chain-polymer structure. The solution must be fairly dilute but viscous enough to be spun using conventional spinning equipment. The cooling of the extrudate leads to the formation of a fiber that can be continuously dried to remove the solvent or later extracted by an appropriate solvent. The fibers are generally postdrawn or stretch oriented. See **fiber processing, gel-spinning; modulus of elasticity; molecular structure; molecular weight; orientation; plastics, theoretical versus actual values of; polyethylene plastic; reinforcement; Spectra; tensile strength.**

fiber processing, spinning, pulsation See **extruder flat-film draw-ratio.**

fiber processing, spinning, reaction A liquid polymer is extruded through a spinneret plate and encounters a chain extending cross-linking component, producing a filament. See **fiber spinneret.**

fiber processing, spinning, row nucleation The mechanism by which stress-induced crystallization is initiated usually during fiber spinning or hot drawing.

fiber processing, wet-spinning A process in which a plastic solution is extruded from a spinneret and immersed into a spin-bath tank containing a circulating nonsolvent solution that coagulates (precipitates) the plastic filaments. Both the solution and the precipitation stages involve chemical reactions. After passing through the spin-bath tank, they are washed prior to the windup. Conventional wet spinning has the slowest line speed compared to the other lines. However, since it permits very short distances between the holes in the spinneret face, a single spinneret may carry a very large number of holes. With this single spinneret, high production rates can still be achieved. Also called *reaction spinning*.

fiber production See **fiber processing.**

fiber property Properties change according to different grades of each fiber. Typical values in lb/in.^{3} (g/cm^3) are: aramid 90.4 (2.55) and E-glass 159.0 (2.55). Their modulus of elasticity in 10^6 psi (10^4 MPa) arc: aramid 27 (18.6), E-glass 10 (6.9), and S-glass 12 (8.6).

fiber, quartz Any high-purity glass but usually a flexible fiber that is produced from high-purity (99.95wt% SiO_2) natural quartz crystals. It is formed from rods having one-fifth the diameter of human hair. Extremely high temperatures are required for liquefaction and drawing. See **fiber, silica.**

fiber, ramie A strong natural fiber of vegetable origin that sometimes is used as a filler or reinforcing material providing high shock resistance and strength.

fiber, rayon A generic term that is used for fibers, staples, and continuous filament yarns composed of regenerated cellulose but also frequently used to describe fibers obtained from cellulose acetate or cellulose triacetate. Rayon fibers are similar in chemical structure to natural cellulose fibers (cotton) except that the synthetic fiber contains short plastic units. Most rayon is made using the viscose process. See **carbon disulphide; cellophane; fiber linter; viscous process.**

fiber, rayon viscose A regenerated cellulosic fiber that is made by treating wood pulp with caustic soda and with carbon disulfide to form cellulose xanthate, which is then dissolved in a weak caustic solution. It is from the latter that extrusion and coagulation forms the fiber. See **carbon disulphide; coagulation; fiber processing.**

fiber reinforced plastic (FRP) A generic term for all fiber reinforced plastics, regardless of process and type of fiber. See **composite; reinforced plastic.**

fiber roving See **roving.**

fiber, shrinkage, molding See **reinforced-plastic molding fiber shrinkage.**

fiber, silica The term *high silica* is used to describe any high-purity glass. For use in reinforced plastics, it is at least 95% pure SiO_2 produced by a leaching process; glass fiber, with a silica content of 65%, is subjected to a hot-acid treatment that removes virtually all the impurities while leaving the silica intact. High-silica fibers and fabrics are flexible materials that are similar in appearance to conventional E-glass fibers. Quartz, somewhat similar to glass and high silica, has 99.95% SiO_2. High silica and quartz are both used in a wide variety of similar products. The selection of what type to use is generally dictated by a combination of performance requirements, manufacturing needs, and cost. Quartz has about five times the tensile strength of high silica, and both have similar thermal characteristics. The major difference is the higher melt viscosity of quartz as a result of its higher silica content. Both do not melt or vaporize until a temperature exceeds 3,000°F (1,649°C). At continuous temperatures in excess of 1,800°F (982°C), both forms begin to denitrify into a crystallized form known as *cristobalite*. This conversion tends to stiffen the materials but causes no change in their physical form. Their products can be heated to 2,000°F (1,093°C) and rapidly quenched in water without any apparent change. See **fiber, quartz; fiberglass; silica.**

fiber, silicon-carbide A reinforcing fiber with high strength and modulus with 2.7 density. The primary purpose for this development was for the reinforcement of metal matrix and ceramic matrix composite structures used in advanced aerospace applications by the military. SiC fibers were developed to replace boron fibers in these composites because boron had drawbacks, principally degradation of mechanical properties at temperatures greater than 540°C (1,000°F) and very high cost. See **chemical vapor deposition; fiber, boron; vapor-liquid-solid process.**

fiber, silk A natural fiber secreted as a continuous filament by the silkworm. See **fiber, spider-silk.**

fiber, sisal A white fiber produced from the leaves of the agave plant found in Central America, the West Indies, and Africa. It is used primarily as cordage, binder twine, reinforced plastics, and so on. When chopped, it is used as a low-cost filler.

fiber sizing See **fiberglass binder/sizing coupling agent.**

fiber skein A continuous fiber, filament, strand, yarn, or roving that is wound up to some measurable length and usually used to measure various mechanical and physical properties.

fiber sliver A staple or continuous-filament fiber that is aligned in a continuous strand without a twist.

fiber, spandex An elastomeric fiber that is principally made from segmented polyurethanes (spandex) and polyisoprene (natural rubber). The elastomeric fibers consist of plastics with a main glass transition temperature (T_g) well below room temperature. This criterion excludes some fibers with elastic properties. The fibers are produced primarily using dry spinning and wet spinning with a few producers using melt spinning. For the natural rubber, a latex mixture is continuously forced through a capillary tube into an acid bath, where it is coagulated; the thread-like coagulum is pulled from the bath followed simultaneously with washing, drying, and curing. See **fiber processing, spinning; glass transition temperature.**

fiber, spider-silk A DuPont fiber that, on an equal weight basis, is stronger than steel, very elastic, and very tough. The combination of strength and stretch makes the energy-to-break very high. This biosynthetic plastic provides a broad range of mechanical properties. See **plastics, theoretical versus actual values of.**

fiber spinning process See **fiber processing, spinning.**

fiber spinneret A type of die that is principally used in fiber manufacture. It is usually a metal plate with many small holes (or oval, etc.) through which a melt is pulled or forced. The holes enable extrusion of filaments of one denier or less. Conventional spinneret orifices are circular and produce a fiber that is round in cross-section. They can contain from about 50 to 110 very small holes. A special characteristic of their design is that the melt in a discharge section of a relatively small area is distributed to a large circle of spinnerets. Because of the smaller distance in the entry region of the distributor, dead spaces are avoided, and the greater distance between the exit orifices makes for easier threading. Precision machining of the orifices is required to avoid differences in thickness between the filaments being pulled. Note that the volumetric discharge from a cylindrical die increases with the fourth power of the diameter. An error of 10% in diameter will cause a 47% error in output. Because these differences in spinneret heads cannot be balanced out by adjusting the individual filament haul-off speeds, the diameter of the monofilament is altered by 21%. Also called *spinnaret.* See **die orifice; fiber denier; fiber processing.**

fiber spool A holder for fibers. See **roving ball.**

fiber, staple A fiber that is made up of a large number of discontinuous, randomly oriented, individual fibers normally shipped in a box or bale. The fibers can be obtained by cutting continuous filament into ½ to 2 in. (12.7 to 50 mm) lengths and 1 to 5 denier or manufactured directly into desired lengths. They are usually subjected to a series of processes, culminating in textile spinning to yarn and are processed like natural fibers, such as wool and cotton, with which they can be blended. See **fiber tow.**

fiber strain gauge See **strain gauge.**

fiber strand See **filament strand.**

fiber, straw A fibrous, cellulosic component of certain plants (wheat, rice, etc.). Its fibers are 1 to 1.5 mm long, similar to those of hardwoods. Straw can be used as filler in plastics. Its main use is preparing a pulp by the alkaline process to yield specialty papers of high quality. The use of straw for conventional papermaking in the United States is of limited importance due to the abundance of pulpwood.

fiber stress, mass Force per unit mass per unit length in grams per linear denier. It is used the same way as force per unit area. See **fiber denier; tensile strength.**

fiber stretch, cold A pulling operation with little or no heat on fibers to increase tensile strength. See **orientation.**

fiber tenacity See **yarn tenacity.**

fiber tex See **tex.**

fiber tow **1.** The precursor of staple fibers is tow, which consists of large numbers of roughly parallel, continuous filaments. They are converted by cutting or breaking into staple fibers or directly into slivers, which are intermediate stages between staple fibers and yarns. In the latter case the filaments remain parallel. See **fiber, staple. 2.** An untwisted bundle of continuous filaments, usually man-made fibers. For example, a tow designated as 140 K has 140,000 filaments. See **filament strand.**

fiber, textile A fiber or filament that can be processed into yarn or made into a fabric by interlacing in a variety of methods, including weaving, knitting, and braiding. These forms of textile are used with plastics to fabricate parts such as high-strength tubes or pipes, electrical and medical devices, and so on. See **fabric, woven; fiber; filament; reinforced plastic; roving, textile; textile; yarn.**

fiber tracer See **reinforced plastic prepreg tracer.**

fiber turn per inch (tpi) **1.** A measure of the amount of twist produced in a fiber, yarn, roving, and so on during its processing. See **twist, direction of yarn. 2.** The lead rate of a hoop layer at a specified band width.

fiber twist See **twist, direction of yarn.**

fiber, V A fiber whose leading flank intersects with the flowing flank of adjacent fiber at the fiber root.

fiber, vegetable Vegetable fibers that are used in plastics include (1) seed-hair-cotton, kapok, milkweed floss; (2) bast-flax, hemp, jute, ramie; and (3) leaf-abaca, sisal.

fiber, vulcanized See **vulcanized fiber.**

fiber wadding A loose cohering mass of fibers in sheet or lap form. See **filament winding lap; joining, lap.**

fiber warp See **yarn warp.**

fiber, wet spinning See **fiber processing, wet-spinning.**

fiber, whisker See **reinforcement, whisker.**

fibril See **stress whitening.**

fibrillation See **fiber fibrillation; fiber processing.**

Fick's law See **devolatilization.**

filament **1.** A single, threadlike fiber or a number of these fibers put together. **2.** A variety of fiber characterized by extreme length, which permits their use in yarn with little or no twist and usually without the spinning operation required for fibers. See **fiber processing.**

filament, glass A form of glass that has been drawn to a small diameter and extreme length. Most filaments are less than 0.005 in. (0.013 cm) in diameter.

filament greige A silk or synthetic-filament term for gray fiber.

filament lay **1.** A length of twist that is produced by stranding filaments, such as fibers, wires, or rovings. **2.** The angle that such filaments make with the axes of the strand during a stranding operation. The length of twist of a filament is usually measured as the distance parallel to the axis of the strand between successive turns of filaments. See **yarn twist, balanced.**

filament, mono- A monofilament is a single filament of relatively indefinite length. They are generally produced by extrusion. Also called *monofill.* See **extruder godet unit.**

filament, multi- A continuous thread that is comprised of several individual monofilaments.

filament roving See **roving.**

filament shoe A device that gathers the numerous filaments into a strand in glass-fiber forming.
filament silver A number of staple or continuous filament fibers that are aligned in a continuous strand without a twist.
filament strand A primary bundle of continuous filaments combined in a single compact unit without a twist. These filaments, usually 51, 102, or 204, are gathered together in their forming operation. See **fiber processing; fiber tow; roving.**
filament-strand end A group of filaments. See **yarn end.**
filament-strand integrity The degree to which the individual filaments making a strand or end are held together by the applied sizing.
filament, stretched See **forming, cold-drawing; orientation.**
filament tenacity See **yarn tenacity.**
filament tex See **tex.**
filament twist See **twist, direction of yarn.**
filament, virgin An individual filament that has not been in contact with any other fiber or any other hard material.
filament winding (FW) A process that produces high-strength and lightweight products that consist basically of two reinforced-plastic ingredients—the reinforcement and a plastic matrix. The process uses a continuous reinforcement (glass, carbon, graphite, PP, wire, and other materials in filament, yarn, and tape form) either previously impregnated (prepreg) or impregnated at the machine with a plastic matrix that is placed on a revolving (removable) mandrel followed by curing. Reinforcements have set pattern lay-ups to meet performance requirements; the target is to have them uniformly stressed. See **reinforced plastic.**
filament winding, ABL bottle See **ABL bottle.**
filament-winding angle The angle measured in degrees between the direction parallel to the filaments and an established reference. It is usually the centerline through the polar bosses—that is, the axis of rotation.
filament winding, axial A filament that is parallel or at a small angle to the rotational axis (0 helix angle).
filament winding, balanced A winding pattern in which the stresses in all fibers or filaments are equal.
filament winding, biaxial Winding in which the helical band is laid in sequence, side by side, with crossover of the fibers eliminated.
filament winding bladder/liner An elastomeric (barrier) lining that contains hydroproof and hydroburst pressurization medium during curing. When a protective inside liner is required, the properly bonded bladder remains in the filament-winding structure. See **barrier plastic.**
filament winding bleedout The excess liquid plastic that migrates to the surface of a winding. See **bleed.**
filament winding butt wrap Tape wrapped around the mandrel in an edge-to-edge condition.
filament winding cake forming The collection (package) of glass fiber strands on a mandrel during the forming or winding operation.
filament winding circuit One complete traverse of the fiber feed mechanism of a filament-winding machine.
filament winding, circumferential Filaments are essentially perpendicular to the axis of rotation.
filament winding closure See **closure.**
filament winding directional property See **directional property.**
filament winding displacement angle The advancement distance of the winding reinforcement on the equator after one complete circuit.
filament winding doff The act of removing a full package such as a roving ball from a winding machine.
filament winding doily Planar reinforced plastic applied to a local area between windings to provide extra strength where a cutout such as a port opening is included.
filament winding dome The spherical or elliptical shell ends of a filament-winding container.
filament winding doubler A local area with extra reinforcement, wound generally with the part or wound separately and fastened to the part.
filament winding, dry-winding Filament winding that uses impregnated roving as differentiated from wet winding. See **reinforced-plastic wet winding.**
filament winding dwell See **dwell.**
filament winding equator junction The line in a tank that describes the junction of the cylindrical portion with the end of the dome. Also called the *tangent line* or *point.*
filament winding gap **1.** The space between successive windings in which they are usually intended to lay flat next to each other. **2.** The separation between fibers within a filament winding band. **3.** The distance between adjacent plies in the lay-up of unidirectional tape materials.
filament winding geodesic-isotensoid contour The dome contour on a pressure vessel in which the filaments are placed on geodesic paths so that they exhibit uniform tensions throughout their lengths under pressure loading. This design produces a pressure container with the combination of providing the highest-pressure loading for the lightest weight. See **design, geodesic isotensoid.**
filament winding geodesic-ovaloid **1.** The contour for end domes where the fibers form a geodesic line. **2.** The shortest distance between two points on a surface of revolution. The forces exerted by the filaments are proportional to meet hoop and mechanical stresses at any point.
filament winding helical path The filament band advances along a helical path but not necessarily at a constant angle except when winding a cylinder.
filament winding knuckle area The area of transition between sections of different geometry such as where the skirt joins the cylinder of a pressure vessel. Also called *Y-joint.*

filament winding lap The amount of overlap between successive windings that is usually intended to minimize gapping. See **joining, lap.**

filament winding lattice pattern A pattern with a fixed arrangement of open voids.

filament winding longs Low-angle or longitudinal windings.

filament winding loop-strength tenacity The tenacity or loop strength value obtained by pulling two loops against each other that can cause the fibrous (particularly glass) material to be cut or crushed.

filament winding mandrel See **bend, radius of; mandrel.**

filament winding, multicircuit Winding that requires more than one wrapping circuit before the band repeats by laying adjacent to the first band.

filament winding netting analysis The analysis assumes that all stresses induced in the reinforced-plastic structure are carried entirely by the filaments and ignores the strength of the plastic. It also assumes that the filaments possess no bending or shearing stiffness and carry only the axial tensile loads.

filament winding pattern To meet different performance requirements, various patterns are used, including hoop or circumferential, helix narrow or wide ribbon, helix low angle, zero or longitudinal, polar wrap, simple or true spherical, and ovaloid.

filament winding planar The winding path lies on a plane that intersects the winding surface.

filament winding planar helix A dome in which the filament path lies on a plane that intersects the dome while a helical path over the cylindrical section is connected to the dome paths.

filament winding, polar Winding in which the filament path passes tangent to the polar opening at one end of the chamber and tangent to the opposite side of the polar opening at the other end. It is a one-circuit pattern that is inherent in the system.

filament winding pole piece A winding in which the filaments do not lie in an even pattern. The supporting part of the mandrel is usually on one side of the axes of rotation.

filament winding prepreg and bag molding A device that is used to obtain special high-performance reinforced-plastic products that require special fiber patterns or high fiber volume content such as 65%. These prepregs can be cut to the required shape and fitted in a mold. See **reinforced plastic bag molding; reinforced-plastic prepreg.**

filament winding radius See **bending, radius of.**

filament winding rail car See **rail car, Glass-hopper.**

filament winding random pattern Winding that has no fixed pattern. If a large number of circuits are required for the pattern to repeat, a random pattern approach can be used.

filament winding reverse helical pattern As the fiber delivery arm traverses one circuit, a continuous helix is laid down, reversing direction at the polar ends, in contrast to biaxial, compact, or sequential winding. The fibers cross each other at definite equators, the number depending on the helix angle. The minimum region of cross-over is three.

filament winding roving See **roving.**

filament winding, single-circuit-pattern A pattern in which the filament path makes a complete traverse of the chamber or mandrel, after which the following traverse lies immediately adjacent to the previous one.

filament winding, slip-angle-pattern An angle at which a tensioned fiber will slide off the filament wound dome. If the difference between the wind angle and the geodesic angle is less than the slip angle, the fiber will not slide off the dome. Slip angles for different fiber-plastic systems vary and must be determined experimentally.

filament winding strength See **ABL bottle; strength.**

filament winding tape See **prepreg tape.**

filament winding tape laying A process in which tape is laid side by side or overlapped to form a structure.

filament winding tension The amount of tension on the reinforcement as it makes contact with the mandrel. The target is to have the required tension uniformly applied to all reinforcements. See **tensile strength.**

filament winding test See **test, NOL ring.**

filament winding, wet-winding The process of winding unimpregnated roving directed toward a mandrel where the reinforcements are impregnated with plastic just prior to contacting the mandrel. See **filament winding, dry-winding.**

filament winding, winding-pattern The total number of individual circuits that are required for a winding path to begin repeating by laying down immediately adjacent to the initial circuit.

fill and wipe See **decorating, fill-and-wipe.**

filler An inert substance (organic and inorganic with low to high weights) that is added to plastics to reduce costs. A filler is usually low in cost and may also improve processing and physical and mechanical properties, particularly hardness, thermal insulation, stiffness, and impact strength. The particles are usually small, in contrast to those of reinforcements. Also called *extenders*. See **additive; ash; binder; calcium carbide; calcium carbonate; carbon filler; carborundum; cellulose, alpha; channel black; coke dust; coral; diatomaceous earth; extender; ferrite; fiberglass, milled; flint; flock; fuller's earth; glass filler; glass sphere, solid; hemp; keratin; lamp black; leather-dust; macerate filler; magnesium carbonate; mica; microsphere; particulate filler; plastic grout; pumice; quartz; reinforcement; sawdust; talc; vermiculite; wood flour.**

filler and property See **testing and classification.**

filler, dolomite A double carbonate of lime and magnesia filler having the formula $(CaCO_3)(MgCO_3)$.

filler, high-loading See **titanate coupling agent.**

filler, inert A filler that is added to plastics to alter the properties of a product through physical rather than chemical means.
filler, mineral A large subclass of inorganic fillers that are comprised of ground rocks as well as natural or refined minerals. Commodity minerals are relatively inexpensive and are used mostly as additive extenders. Other fillers, so-called specialty minerals, are usually the reinforcing types. There are also inherently small-particle-size fillers such as talc and surface chemically modified fillers. See **aggregate; china clay; oil; volcano.**
filler softening See **stress softening.**
filler versus unfilled compound Fillers are used to reduce the cost of material, and simply adding filler to a plastic does not automatically ensure savings. The density and cost of both the filler and plastic play an important role in determining the savings compared to unfilled. As an example, by adding 30wt% of mineral filler like talc to medium-impact polystyrene (s.g. 2.5 to 3.1) reduces the amount of plastic by only 15%. But if a low-density filler like wood flour (s.g. 0.5; other types range from 0.2 to 1.5) is used in the same weight percentage, the specific gravity (s.g.) of a part is reduced to 0.79. Plastic content saving of 47wt% occurs compared to unfilled material. See **blending; compounding.**
fillet A rounded filling of the internal angle between two surfaces of a part. See **joining, fillet.**
filling gap See **adhesive gap filling.**
film A plastic material that has a nominal thickness not greater than 0.010 in. (0.025 cm). Primarily extruders and calenders form thermoplastic films. Other processes include solvent casting, chemical conversion, and skiving from solid rolls. See **calender; extruder-blown film; extruder flat film.**
film and sheet thickness See **die, film and sheet thickness for a.**
film bactericide See **bactericide.**
film, barrier A barrier structure for flexible packaging films. See **barrier plastic.**
film blocking The cohesion between touching layers of plastic films or sheets, such as the one that may develop under just slight pressure loading during storage or use. The extent of blocking depends on temperature, pressure, humidity, physical properties of the plastics, additives surfacing the film, or processing conditions. If the plastic has a low softening point or if it picks up moisture readily, it will have a greater tendency to block than a plastic that has a high softening point and does not pick up moisture. The physical properties of the plastics on which blocking depends include the following: (1) smooth surfaces adhere more readily than rough surfaces; (2) adhesion will depend on the amorphous or crystalline character of the plastic with amorphous having a greater tendency to block; (3) if one surface is readily wet by the other, the tendency to block is increased; (4) if the melting point is low, there will be an increased tendency to block; (5) if the surface shows flow under pressure, the tendency to block may be severe; (6) blocking is promoted by the tendency of the film to pick up water vapor; and (7) films and sheets that develop static electricity readily adhere to each other.

Surface blocking is more of a problem with blown-film than with flat-film extrusion. The inflatable bubble travels at higher speed and, cooled only with air, is squeezed together and wound for only a few seconds after leaving the hot die lands. Blocking may occur on the inside or outside of the tube, or in extreme cases, both inside and outside. Thicker films are easier to separate than thinner ones because of better transmission of shear forces applied (for example, during bag opening). An excess of film surface treatment, which is used for good printing ink adhesion, frequently causes blocking. The treatment drives off additives (slip additives, antiblocking agents, etc.) and enhances blocking. See **additive, slip; antiblocking agent; antistatic agent; dusting agent; lubricant; sheet blocking.**
film, blown See **extruded-blown film.**
film, breathable See **packaging, breathable-film.**
film capping See **coextrusion capping.**
film, cast **1.** Film (or sheet) that is produced by pouring or spreading plastic solution or melt over a suitable temporary substrate, followed by curing via solvent evaporation or melt cooling and removing the cured or solidified film from the substrate. See **casting, solvent. 2.** Cast films are extruded film that are cooled usually by having the film pass through a water tank or under blown air using guide features. See **casting; extruder flat film.**
film, clinging Film that either clings or sticks to itself or to other materials. It is widely used in packaging. See **packaging; thermoforming.**
film coating See **coating.**
film decorating Improving the surface of fabricated parts using decorative film includes all measures that are carried out during or after fabrication. The result is protection (hardening, barrier properties, etc.), technical effects (metallic characteristics, nonslip, etc.), individual optical effects (replaceable interior or exterior auto parts), information (operating instructions, etc.), publicity (printed images, logos, etc.), part defects (covering flow or weld lines, etc.), or decoration (color, gloss, matting, etc.). In many cases the surface is subsequently colored or provided with other effects that, for economical or technical reasons, can be applied only incompletely, if at all, during fabrication. Reasons for this action include insufficient smooth surface due to processing, plastic material with an undesirable color, only certain areas of a molded part are to be decorated, or plastic surface is required to be harder. See **decorating; electrical corona discharge treatment; foil decorating; in-mold decorating; surface treatment; texturizing.**
film, electrostatic charge Electrostatic charges on films and other plastics attract dust and other foreign materials that ruin product appearance, produce tearing or jamming of online operations, or subject people to a sudden (zapping) static discharge. Static eliminators or ionizing

bars are used to eliminate these charges. See **electrostatic charge.**

film, flat See **extruder flat film.**

film formation Virtually all thermoplastics can be used to produce film. Most films are produced using extruders (flat film and blown film), calenders, and solvent castings. See **polymerization, electron-beam.**

film insert molding See **molding, film-insert.**

film, laminated Thermoplastic film that has been laminated to substrates such as plastic film or sheet, paper, aluminum foil, and so on. See **inlay or overlay; laminate.**

film light transmission See **light densimeter; light transmission.**

film, liquid oxygen compatibility See **polyarylene ether phosphine oxide plastic.**

film market Total sales of film in the United States are at least $22 billion (6.4 million tons). About 72,000 people are employed in the industry. Film represents the largest single product produced from plastics, with its major market being in the packaging market. See **agriculture market; market.**

film, parting See **reinforced plastic bag-molding parting film.**

film perforating The process by which plastic film or sheeting is provided with various-size holes, from rather large holes for decorative effects (by means of punching or clicking) to very small, even invisible sizes. The latter are attained by spark erosion or by passing the material between rollers or plates, one of which is equipped with closely spaced fine needles. See **electroerosive cutting and sinking.**

film, pressure-detecting See **pressure-detecting film.**

film, reflective See **extruder-blown film die, coextruded-reflective.**

film scrap See **densifier.**

film, skived A film that is produced by shaving off a thin film or sheet layer from a large block of solid plastic, usually a round billet. Continuous film is obtained by skiving in a lathe-type cutting operation, similar to producing plywood that is cut from a tree trunk log. This process is particularly useful with plastics that cannot be processed by the usual plastic film processes such as extrusion, calendering, or casting. For example, PTFE is a plastic that is not basically granulated and processable using conventional fabricating methods. See **extruder wire and cable, ram; ingot; material, billet.**

PTFE powder is put into a mold to make billets. Powder is compressed uniformly (carefully) at pressures of 2,000 to 5,000 psi (14 to 34 MPa). This preform is removed from the mold and sintered by heating unconfined in an oven at temperatures 680 to 715°F (360 to 380°C) for times ranging from a few hours to several days depending on the size and shape of the billet. Billet sizes go from 2 to 1,600 lb (1 to 726 kg), among the largest thermoplastic moldings made of any plastics. Time with temperature variation during cure is closely controlled. The target is a final cure without voids and other defects that periodically occurs usually internally. Defective billets are not conducive to good film skiving and are not recyclable.

film slippage and tearing See **extruder-web tension control, slipping and tearing.**

film spreader See **doctor blade; extruder roll, spreader/expander.**

film, surface-treating See **electrical corona discharge treatment; surface treatment.**

film thickness See **radioisotope; sensor.**

film thickness is 4 μm See **fabric, nonwoven flash-spun.**

film, thin See **parylene plastic; spectroscopy position-annihilation.**

film toughness test See **test, ball-burst film impact.**

film, transparent conductive See **electrical transparent conductor.**

filter A device that is used to separate material particles from melts, fluids, or air. Filters can be porous, fibrous, or granular. See **colloidal ultrafiltration; diatomaceous earth; dust collection, bag-filter; sensor, inductive and capacitive proximity.**

filtration, fiber See **fiber-processing filtration.**

filtration, ultra- The separation of colloidal or very fine solid materials by filtration through microporous or semipermeable mediums. See **diatomaceous earth.**

fin An edge that protrudes from the surface or excess material that is left on a fabricated part such as those places where a mold or die has mating surfaces. Fin also can exist in holes or the openings of a part. Different treatments are used to remove the fins if the process cannot correct the problem. See **die; mold; surface finish.**

Finagle's law See **fabricating, Finagle's law of.**

fine A very small particle, usually under 200 mesh, that accompanies larger forms of molding powders that are developed when granulating plastics. When plastics are extruded and pelletized, varying amounts of oversized pellets and strands are produced, along with fines. When the plastics are dewatered, dried, or pneumatically conveyed, more fines, fluff, and streamers may be generated. Usually they are detrimental during processing so they are removed or action is taken to eliminate the problem during grinding scrap, etc. See **dicer; pelletizing.**

finish **1.** To complete the secondary finishing work on certain parts after they are fabricated, such as with deflashing, buffing, tapping, degating, and machining. See **burnish; polish; surface finish; surface treatment; tumbling. 2.** The surface treatment of parts based on molds, dies, and other tools are available from industry. See **mold-cavity surface; surface finish. 3.** See **decorating; fiber finish; wax.**

finish, baking A coating, paint, or varnish that requires a baking temperature greater than 66°C (150°F) for the development of desired properties. Such finishes are based on epoxy oil-modified alkyd, melamine, and so on. Baking, usually by infrared, produces high-molecular-weight finishes that are dense and tough. See **coating; infrared; molecular weight; paint; varnish.**

finish, barrel burnishing The smoothing of surfaces by means of tumbling, such as a ball mill.

finish, blast The process of removing flash from (usually) thermoset molded plastics or dulling surfaces of thermoplastic or thermoset plastics. An impinging medium, such as steel balls, crushed apricot pits, walnut shells, or plastic pellets, is used with sufficient force. When the plastic is not sufficiently brittle, it can be chilled. The majority of machines are batch types comprised of wheels rotating at high speeds, fed at their centers with the media, which is thrown out at high velocity against the parts. Some continuous machines allow a speed-controlled, open wire-screen conveyor belt to be used. See **deflashing; flash; polish; surface finish.**

finish, bright A laminated plastic decoration that indicates a glossy surface finish.

finishing, ashing and lapping A plastic part is seldom ashed or lapped. It is necessary only to use abrading techniques when models are machined from plastic blocks. Ashing produces a satinlike surface, but subsequent polishing is required to secure a lustrous finish. The process is done on a wheel that is usually built up of muslin disks, preferably not sewed together. Wet pumice is applied between the work and the ashing wheel. The pumice is wet to accelerate the cutting and also retard excessive dusting. The part should be washed as soon as it is ashed and promptly dried. Lapping is an operation similar to ashing except that the work is done on the side of the wheel instead of the periphery. A lapping wheel consists of a flat, metal disk on the end of an arbor or shaft. To the surface is cemented heavy felt, and in turn wet pumice is applied. The part is pressed against this surface. See **ashing; beeswax; buffing; polish; sanding; surface finish; wax; wet ashing.**

finishing, barrel The cleaning, smoothing, and polishing of plastic and metal parts by mechanical friction, which is obtained by placing them in a drum or barrel that rotates on the horizontal axis. An abrasive medium is used in the container with water usually added. The containers often include vertical dividers to make two or more compartments that can be individually loaded and unloaded.

finishing, mass There are three basic types—namely, barrel, vibrator, and centrifugal systems. When used properly each system produces good-quality parts. Where they differ is in their speed and cost; the faster the system, the more expensive.

finish, matte A surface with a dull, nonreflective finish.

finish, pre- The finish of a processed plastic part, such as the parting line of threads, closures, or flash.

finish, surface See **surface finish.**

finish system, reduced solvent A finishing system that replaces conventional solvents with carbon dioxide to reduce volatile organic compound (VOC) levels to meet emission standards. See **carbon dioxide; solvent; Unicarb; volatile organic compound.**

finite-element analysis (FEA) A computer analysis that provides a means to theoretically predict the structural integrity of a part using mathematical geometry and load simulation. A stress analysis can be taken of finite sections for analysis of the forces and loads the part will experience in service. It generates an analysis that shows the force concentrations in the section and determines if the material and design shape selected will be OK. See **computer finite-element mesh operation; die shape; performance prediction.**

fire The manifestation of rapid combustion or the combination of materials with oxygen. It is the destructive burning as manifested by any or all the following: light, flame, heat, electricity, and smoke. See **autoclave nitrogen atmosphere; burn; combustible; combustion; flame extinguished; flammability; ignition temperature; limiting index oxygen; smoke emission; test, fire cone and lift; test, tunnel fire.**

fire and plastic The fire or flammability properties of plastics vary from those that burn easily to those that do not burn. Fire requirements are determined based on fire tests, standards, or specific requirements. The $2.3 million Tiffany Street Pier in the borough of the Bronx, New York City, is one of the largest single uses of "plastic lumber" that was extruded from recycled plastic into boardlike shapes. It measures 410 ft (125 m) long by 49 ft (15 m) wide with a gazebo and was built in 1995. In 1996 it was hit by lightning and, as reported by the fire experts, it survived better than if it had been a traditional wooden pier even though one-third of the plastic was damaged. The damaged section was replaced with the extruded plastic lumber.

fire and plastic solvent See **chlorinated compound solvent.**

fire, back-flash See **back-flash.**

fire cone and lift, test See **test, fire cone and lift.**

fire drill See **training crisis.**

fire hazard See **dust, industrial.**

fire index See **Underwriters' Laboratory fire resistance index.**

fireproof agent See **flame retardant; zinc carbonate.**

fire resistant The ability of a structure to perform its function satisfactorily during and after a fire or give protection from it. See **coating, intumescent; flame retardant.**

fire retardance The resistance to combustion of a material when tested under specified conditions. See **flammability; ISO; limiting index oxygen; Underwriters Laboratory classification; zinc borate; zinc carbonate.**

fire retardant A material that resists ignition and the spread of flame across its surface.

fire risk See **risk, fire.**

fishbone diagram A technique that is used to list all the variables and steps in a solution to a problem (Ishikawa diagram). All contributing elements are associated with each factor and are taken back to their starting point to ensure that all variable elements are considered. See **graphical database.**

fish-eye A fault that appears particularly in transparent or translucent plastics, such as film or sheet, as a small globular mass that has not completely blended into the surrounding material. Its cause includes incomplete material blending, processing variations, or environmental conditions that include overstress. Also called *cat's-eye.* See **defect; globule; processing window.**

fissure A surface split or crack with narrow openings.

fit See **design, clearance-fit; design, snap-fit; joining-and-bonding method; welding.**

fit, interference A mechanical fastening method that is used to join two parts, with friction holding the parts together. For example, a plastic hub and a shaft may have the external diameter of the shaft larger than the internal diameter of the hub. This interference could produce high stress in the material and must be determined carefully to avoid exceeding the allowable stress for the plastic. Stress relaxation can occur in interference fits, causing the joint to loosen over time. Also called *press-fit.* See **design, maximum diametrical interference.**

fit, pre- A process for checking a fit of mating detail parts in an assembly prior to permanent attachment, such as adhesive bonding or mechanical fastening, to ensure proper lineup and attachment lines.

fixing agent **1.** A mechanical substance (albumin) that is capable of holding pigments permanently. See **pigment.** **2.** A gum or starch that holds dyes and other substances mechanically on textile fibers long enough to be processed. **3.** A substance that aids fixation of mordents on textiles by uniting chemically with them and holding them on the fiber until the dyes can react with them.

fixture In assembly of parts, a device that is used to align and support the parts. See **assembly/joining.**

flake **1.** A form of plastic raw material that is processed. **2.** The dry, unplasticized base of cellulosic plastics. **3.** See **glass flake; scale.**

flame A hot, usually luminous zone of gas, of particulate matter in gaseous suspension, or both, that is undergoing combustion. See **combustion; flammability; ignition temperature; smoke emission.**

flame annealing Annealing in which the heat is applied directly by a flame. See **annealing.**

flame extinguished A self-extinguishing material that will burn in the presence of a flame but will extinguish itself within a specified time after the flame is removed. This term is not universally accepted.

flame proofing See **antimony trioxide.**

flame resistance The ability of a material to extinguish a flame once the source of heat is removed.

flame retardant A material that reduces the tendency of plastics to burn or not burn; inherent characteristic of most thermoset plastics. Others can be modified to reduce or eliminate the tendency of the plastic to burn. They are usually incorporated as additives during compounding, but sometimes they are applied as a coating to the parts surface. Different additives can be used to meet different processing capabilities or product performances that will not burn or will be self-extinguishing. The mechanisms of flame retardation vary depending on the nature of material and flame retardant. Types include aluminatrihydrates, antimony oxides, borate bromines, chlorines, magnesiums, melamine phosphates, molybdenums, and phosphates. Popular and very useful types are the brominated compounds, which create toxic dioxins; the industry is working on a substitute for them, which is a difficult task since they are extremely efficient as flame-retardants. There are retardants that yield a substantial volume of coke on burning, which prevents oxygen from reaching inside the material and blocks further combustion. See **alumina trihydrate; antimony oxide; antimony pentoxide; coating, intumescent; fire resistant; phosphorous-base flame retardant.**

flame retardant coating See **coating, intumescent.**

flame spraying See **coating, coil; coating, flame-spraying.**

flame spread index See **test, flame spread index.**

flame treating Method of rendering inert thermoplastic parts, such as polyethylene and polypropylene, receptive to inks, lacquers, paints, adhesives, and so on. They are exposed to less than a second of an open flame, which oxidizes the surface, making it more receptive. See **chemical etching; chemical surface treatment, plastic; decorating pretreatment; surface treatment.**

flammability The measure of the extent to which a material will support combustion. Also known as *inflammability.* See **burned; burning rate; fire retardant; flash; heating, catalytic; incineration; limiting index oxygen; smoke emission; test, tunnel fire.**

flammability, adiabatic See **adiabatic flame temperature.**

flash **1.** See **deflashing; molding flash line.** **2.** In welding thermoplastics, the molten plastic that seeps out of the joint area during the welding process.

flashing, vacuum The heating of a liquid that, on release to a lower pressure (vacuum), undergoes considerable vaporization (flashing). Also called *flash vaporization.*

flash land See **mold land.**

flash line, molding See **molding flash line.**

flash point The lowest temperature at which a combustible liquid will give off a flammable vapor that will burn momentarily.

flash scarfing The removal of flash or bead by a cutting operation. See **cutter; flash.**

flash-spun nonwoven fabric See **fabric, nonwoven flash-spun.**

flat film See **extruder-blown film; extruder flat film.**

flatness and warpage See **warpage.**

flavor See **odor.**

flavor test See **organoleptic.**
flaw See **troubleshooting flaw.**
flax See **fiber, flax.**
flexibility The property of a material by virtue of which it may be flexed or bowed repeatedly without undergoing rupture. See **rigidity; temperature flexibility, plastic.**
flexibilizer additive A substance that is added to fabricated parts to make them more flexible or tough. See **plasticizer.**
flexible mold See **mold, elastomeric.**
flexible packaging See **packaging, retortable-pouch.**
flexographic printing See **printing, flexographic.**
flexometer See **test, flexometer.**
flexural, apparent A measure of the relative stiffness of a material that is taken without pertinent property data. Also called *stiffness in flexure.* See **modulus, flexural.**
flexural life The number of cycles that are required to produce a specified state of failure in a specimen that is flexed in a prescribed method. See **deflection temperature under load versus crystallinity; test.**
flexural modulus See **modulus, flexural.**
flexural property The reaction of physical systems to flexural stress and strain. It is a function of load at a given strain rate, support span, shearing action, and specimen geometry (width and depth). See **bend, free; test, cold-bend.**
flexural rigidity A measure of rigidity of a plate under load in in./lb (cm/kg); thus $d = Eh^3/[12(1 - v)]$, where E = modulus of elasticity, h = thickness of plate, and v = Poisson's ratio. See **design, Poisson's ratio in; modulus of elasticity.**
flexural short-beam shear (SBS) A test of a specimen having a low test span-to-thickness ratio such as the usual of 4:1, such that failure is primarily in shear.
flexural strength The maximum stress of a test specimen loaded to failure in bending, with load applied perpendicular to its surface. Also called *modulus of rupture, bending strength,* or *cross-breaking strength.* See **modulus of rupture; strength.**
flexural strength, biaxial The maximum stress in a biaxial mode of flexure that a specimen develops at rupture. This stress will normally be the calculated maximum radial tensile stress at the center of the convex surface. This mode of flexure is a cupping of the circular plate caused by central loading and supporting near the rim. See **directional property, biaxial; orientation, biaxial.**
flexural strength, wet The flexural strength after water immersion, usually after boiling the test specimen for two hours in water. This test can relate mechanical performances for plastics, particularly reinforced plastics.
flexural stress The maximum stress in a specimen at a given strain rate in a specific bending test such as a simple beam supported at two points and loaded at the midpoint. See **stress-strain curve.**
flexural testing Other methods of flexural testing, other than the usual 3-point test, include the cantilever beam method. It is used in creep and fatigue testing and for conducting tests in different environments. See **deflection; test, deflection temperature under load.**
flexural test, short-beam shear (SBS) A 3-point flexural test of a specimen having a low test span-to-thickness ratio, such as 4:1, with a result that failure is primarily shear. It is particularly applicable in testing reinforced plastics or plastic compounds with high additive contents. See **compound; reinforced plastic; shear.**
flint Natural rock of very fine-grained silica that is used as a filler.
floating platen See **platen, floating.**
floc Small masses that are formed in a fluid through coagulation, agglomeration, or biochemical reaction of fine suspended particles.
flocculating agent A reagent that is added to a dispersion of solids in a liquid to bring together the fine particles to form flocs. Also called *flocculent.*
flocculation The formation, sometimes reversible, of a loosely coherent, partially agglomerated elastomer, distributed in the liquid phase of a latex. See **cationic reagent.**
flocculent To cause to aggregate or coalesce into a flocculent mass.
flock Very short fibers that are used as fillers in plastic materials and can improve processing or properties or reduce cost. Fibers are reduced to fragments by cutting, tearing, or grinding, producing different forms that include entangled fiber, small bead size, or usually broken fibers.
flocking A method of coating by spraying finely dispersed powders or fibers by pneumatic or electrostatic means on an adhesive coated surface, producing a velvety surface. Another method takes preheated parts that are dropped into a bed of powder or fibers. Fibers used include nylon, rayon, cotton, or polyester. It provides an attractive or decorative surface, sound absorber, and so on. Also called *flock spraying.* See **coating, coil; powder coating.**
flood coating See **coating, flood.**
flooding See **coating, flood; mold cooling, flood; migration.**
flooring See **aggregate; polyvinyl chloride plastic; vinyl composition tile.**
floppy disk A personal computer magnetic memory disk that is made of flexible plastic film. It stores up to several million bytes of date. See **compact disc.**
flotation agent See **calcium sulfide.**
flour An organic, finely ground filler, extender, or reinforcement such as wood and shell flour, that is added to plastics. See **additive; filler versus unfilled compound; shell flour; wood flour.**
flow **1.** A qualitative description of the fluidity of a plastics material during processing. See **consistency.** **2.** The deformation of a material under the action of a sustained hot or cold force. See **Euler equation.** **3.** The movement of plastic melt under pressure, allowing it to fill all parts of a mold or fill the orifice or opening of an extruder die. See **transport property.** **4.** The gradual

but continuous distortion of a product under continued load, usually at high temperature. Also called *creep*. See **test, cup-flow.**

flow, capillary tube See **viscosity, Hagen-Poiseuille law of.**

flow chart A lined diagram chart that traces a process from start to finish. See **algorithm.**

flow coating See **coating, flow.**

flow, cold A plastic exhibits cold flow when it does not return to its original dimensions after being subjected to stress or load at temperatures well within its usual operating range. A part of such deformation is sometimes recoverable when the stress has been removed. See **creep; deformation under load.**

flow cup test See **test, cup-flow.**

flow, drag The mechanism by which plastic melt is caused to resist flow. For example, a single screw extruder builds up pressure and develops drag-flow effects. The plastic melt must wet both screw and barrel to produce drag-flow effects. See **screw drag flow.**

flow effect, Weissenburg See **Weissenburg effect.**

flow, Ellis model See **viscosity, non-Newtonian flow Ellis model.**

flow, irreversible See **rheology.**

flow, laminar See **melt flow, laminar; flow, viscous.**

flow line See **weld line.**

flow mark A wavy surface appearance on a sheet across extrusion machine transverse direction that is caused by improper flow of the melt leaving the die. A similar action can occur when improper melt enters an injection molding mold.

flow, melt See **melt flow.**

flow model Many mathematical modes exist for describing the flow behavior of non-Newtonian fluids. Their starting points use the basic isothermal Newtonian concept with modifications to fit a physical situation. The usual has a fluid located between two parallel plates where one moves and the other is stationary. See **isothermal; modeling; mold-cavity melt-flow analysis; pressure flow; viscosity, non-Newtonian flow Ellis model.**

flow meter A device that is used to read the volumetric flow rate of a material. See **venturi.**

flow molding See **molding, flow.**

flow, plastic The measure of the deformation of a plastic under load.

flow, plug A flow condition during the processing of plastic in which the velocity across the melt stream, such as in an extrusion die or injection mold cavity, is essentially constant. See **design-mold basics of flow.**

flow, Poiseuille An alternate name for pressure flow in general but often for axial streamline flow in a circular cross-section pipe for which Poiseuille law holds for Newtonian fluids. See **melt-flow analysis problem; pressure flow; viscosity, Hagen-Poiseuille law of.**

flow promoter See **processing stabilizer.**

flow test, thermoset See **test, thermoset-flow.**

flow test, Canadian See **test, Canadian melt-flow.**

flow, viscous A type of fluid in which all particles of the fluid flow in a straight line that is parallel to the axis of a container pipe or channel with little or no mixing or turbidity.

flow, workability The flowability for a material to fill forms and molds without the presence of large voids.

fluid-bed process A bed of powdered or granular material, such as quartz sand, that can be made to behave like a liquid in many respects when a gas stream is passed through it at a particular velocity. Examples of applications include the coating of materials (plastic, metal, etc.), the cracking of some oil fractions, and the calcining of iron pyrites and chalk. In the pyrolysis of plastics the process facilitates rapid heat transfer in a closed reactor without moving parts. See **coating, fluidized-bed; coating, fluidized-bed metal stripping; catalyst, fluid; coating, flood; extruder back-pressure-relief port; fluid-bed process; powder coating; salt bath.**

fluid catalyst See **catalyst, fluid.**

fluid, immiscible See **immiscible.**

fluidity The rate of flow. The term is the reciprocal of viscosity. See **impregnation, introfaction.**

fluorescence A type of luminescence in which an atom or molecule emits visible radiation in passing from a higher to a lower electronic state. The term is restricted to a phenomenon in which the time interval between absorption and emission of energy is extremely short (10^{-8} to 10^{-3} s). This distinguishes fluorescence from phosphorescence in which the time interval may extend to several days. See **krypton; luminescent pigment; pigment, fluorescent; spectroscopy.**

fluorescence and processing See **processing via fluorescence spectroscopy.**

florescence, resonance See **spectroscopy, absorption.**

fluorescent The optical effect produced when light is absorbed by a substance and emitted as light of another wavelength. Ultraviolet light, which is invisible, is emitted as visible light when it strikes a liquid or solid fluorescent substance. See **spectrograph, x-ray fluorescence; Stoke's law.**

fluorescent brightening agent An additive that is used to improve the apparent whiteness of plastics or to counteract the faint yellowish tinge inherent in certain plastics. See **optical brightener agent.**

fluorescent light See **krypton.**

fluorescent pigment See **pigment, fluorescent.**

fluorescent process See **spectrograph, x-ray fluorescence.**

fluorescent whitening agent See **pigment, fluorescent.**

fluorinated ethylene propylene plastic (FEP) A thermoplastic in the family of the fluorocarbons. It is a copolymer of PTFE and hexafluoropropylene that has good weatherability, low dielectric constant, low flammability, low coefficient of friction, and high chemical resistance. This FEP has decreased tensile strength, wear resistance, and creep resistance when compared to the base polymers. It is useful up to 200°C; above that point FEP decomposes, releasing toxic products. With its low melt viscosity, it is easy to process by conventional equipment (extruder, injection molding, powder coating, etc.).

fluorination The process of chemically reacting a material with fluorine-containing compound to change its surface properties during or after its fabrication. It is done in-process during blow molding, adhesive bonding, printing, and so on. Posttreatment includes the use of a closed or sealed chamber where the part is exposed to the gas. For example, it can improve the gas barrier of PE to nonpolar solvents. See **barrier via chemical modification; gasoline tank permeability; sulfonation; surface CASING; surface treatment.**

fluorine (F) A very reactive nonmetallic element. A pale yellow gas that is both corrosive and poisonous, it reacts vigorously with most oxidizable substances at room temperature and forms fluorides. It is used to produce different fluorocarbon plastics. See **halogen; perfluoromethylvinyl ether elastomer.**

fluorocarbon plastic See **fluoroplastic.**

fluorochemical See **chemical, fluoro-.**

fluoroelastomer A class of synthetic elastomer that is designed for demanding service application, such as excellent resistance to corrosive fluids, other chemicals, and high temperatures. Also called *fluorine rubber.*

fluoroplastic A family of thermoplastics that is analogous to the polyethylenes in which some of the hydrogen atoms attached to the carbon chain are replaced by fluorine or fluorinated alkyl groups. In some cases, other halogens such as chlorine are also part of the molecule. Available fluoroplastics include polytetrafluoroethylene, polyfluorohydrocarbon, polyfluorocarbon, fluorohydrocarbon plastic, fluorocarbon plastic, ethylene chlorotrifluoroethylene plastic, and ethylene-tetrafluoroethylene plastic. These TPs provide excellent chemical resistance, antifriction properties, thermal stability, antiadhesive properties, low flammability, and weatherability. However, they have low creep resistance and strength with insufficient ease of processing; certain conditions in processing are used because of their melt characteristics. Their properties and processability depend on the content of fluorine. Applications include electrical and electronic uses, pipe and tubing, and chemical processing equipment. Also called *fluoropolymer* or *fluorocarbon.* See **adhesive surface sodium treatment; cryogenic property; molecule; polychlorofluorocarbon; trifluorochloroethylene plastic.**

fluorosilicone plastic (FS) A synthetic plastic that is a combination of organic and inorganic materials. FSs are made up of alternating silicon and oxygen atoms with trifluoropropyl pendant groups. Most FSs are elastomers or rubbers.

fluted core See **core, fluted; sandwich core material.**

fluxing The preparation of a plastic composition to improve melt flow. For example, fluxing is used in calendering lines for preparing PVC materials. The equipment can include batch-type Banbury mixers, Farrel continuous mixers (FCMs), Buss Ko-Kneaders (BKKs), and planetary gear extruders (PGEs). Dry blend is fed into the mixer or extruder. Excellent mixing within a short dwell time and heat transfer control contribute to an improved product. During fluxing, each particle receives the same "gentle" treatment, generating less heat history and producing a more uniform feed rate, color, gauge thickness, web surface, and so on. The feed can discharge onto a two-roll mill. Operating this way, it provides a second fluxing action, mainly for working in scrap or for convenience as a buffer. See **mixer.**

food container See **packaging; Petlite.**

foam A flexible to rigid material that contains many cells (open, closed, or both) dispersed throughout the material. Foamed products, whether thermoplastics or thermosets, have played a large part and are in a special category within the plastics industry. Foam's apparent density is decreased by the presence of numerous cells throughout the mass; it is a two-phase gas-solid system in which the solid is continuous and composed of plastic material. Also called *cellular plastics, expanded plastic foams, structural plastic foams,* and *plastic foams.* See **expandable plastic; polymer, reactive.**

foamed air-flow level The volume of air per minute at standard temperature and pressure that is required to maintain a constant pressure differential of 125 Pa (0.5 in. of water) across a flexible foam specimen about 50 × 50 × 25 mm (2 × 2 × 1 in.). See **conservation of matter, law of.**

foam and blowing agent A substance that is used for the production of plastic foams. Depending on the basic plastic and process, different blowing agents are used to produce gas and thus to generate cells or gas pockets in the plastics. They are divided into the two broad groups of physical blowing agents (PBAs) and chemical blowing agents (CBAs). The compressed gases often used are nitrogen or carbon dioxide. These gases are injected into a plastic melt in the screw barrel under pressure (higher than the melt pressure) and form a cellular structure when the melt is released to atmospheric pressure or low pressure. The volatile liquids are usually aliphatic hydrocarbons, which may be halogenated, and include materials such as carbon dioxide, pentane, hexane, and methyl chloride. Polychlorofluorocarbons were formerly used but have now been phased out due to reported environmental problems. Also called *foaming agents.* See **aeration; antifoaming agent; azodicarbonadide; carbon dioxide; environmentally friendly additive; expandable plastic; foamed plastic, mechanical; hydrochlorofluorocarbon; molecular sieve; nitrogen; pentane gas; Petlite; polychlorofluorocarbon.**

CBAs, generally solid materials, are of two types: inorganic and organic. Inorganics include sodium bicarbonate, by far the most popular, and carbonates such as zinc or sodium. These materials have low gas yields, and the cell structure they create is not uniform. Organics are mainly solid materials designed to evolve gas within a defined temperature range, usually called the *decomposition temperature range.* This is their most important characteristic and allows control over gas developments through both pressure and temperature. This increased control of the CBAs produces a finer and more uniform cell structure as well as better surface quality on the foamed plastic. There are dozens of different types available that decompose at temperatures from at least 220 to 700°F (105 to 370°C) and possibly higher. Many of these CBAs can be made to decompose below their decomposition temperature through the use of activators.

Recognize that only certain CBAs can be used with certain plastics. They have to be compatible chemically and start gassing at the required temperature. If they are not compatible, different problems develop, such as discoloration and property losses. A CBA with a temperature over the melting temperature of the plastic will not form gas.

foam and process Almost all plastic fabricating processes and plastics are used to produce foamed products, such as the popular cups and dishes, insulating containers, pipes and profiles, and buns. The major techniques use expansion by a blowing agent; some foam is produced by mechanical agitation. For example, extruded sheets can be made on a tandem line using two extruders. The first extruder prepares the melt that is fed into the second extruder, which provides a uniform temperature to the melt prior to forming a foamed tube through its die. This tube is slit into two halves. Two flat foamed sheets go downstream to windup rolls. A single extruder can be used; it is not as efficient in the melt temperature final control when certain plastic mixes with blowing agents and additives are used or tight performance requirements exist. However, this single-stage extruder is widely used because of its economic advantages. See **blow-molding coextrusion foam; coextrusion foam core; coinjection molding; extruder cooling and takeoff equipment; foamed casting; injection molding, foamed gas counterpressure; injection molding, foamed high-pressure; mold, collapsible-core; reaction injection molding.**

foam and process cell structure Depending on how they are processed, foams are available with open-celled construction (reticulate), closed, interconnecting construction, or their combinations. Their densities usually range from 0.1 to over 60 lb/ft^3 (1.6 to over 960 kg/m^3). They can be rigid, semirigid, or flexible as well as colored or plain. They offer advantages such as insulation, cushioning, cores for sandwich construction, and many more. Foamed plastics, like their solid counterparts, can be used for almost an unlimited range of products. An architectural example was an R&D project in 1966. Dome-shaped buildings in Lafayette, IN, were built using PS foamed boards that used the Dow Chemical patented spiral-generation technique. The self-supporting domes required no internal or external support during or after manufacture; they provided their own insulation, and it was easy to cut out sections to create openings for doors, windows, and connecting halls from dome to dome. Their outsides were covered with steel wire mesh and concrete and then waterproofed. The inside walls were covered with appropriate plaster and paneling. See **reticulate.**

foamed, anti- See **antifoaming agent; defoamer additive.**

foamed block A segment of foam that is cut off from continuously produced slabs of foam using different foam-processing techniques. Also called *bun.* See **expandable polystyrene block molding; press, block.**

foamed, blow molded See **blow molding coextrusion foam.**

foamed blown, cellular The volume expansion during the production of foamed/expanded plastic.

foamed blown CO_2 Carbon dioxide for blowing that is generated by chemical reaction between water and the isocyanate plastic. Also called *water-blown foam.* See **carbon dioxide.**

foamed buffer See **buffer.**

foamed bun A large block of foam that can be cut into any desired shape. See **foamed sheet stock.**

foamed casting A simple nonmechanical version of reaction injection molding or liquid injection molding. Foaming components are poured into a mold cavity that is usually heated.

foamed cell A cavity that is left in a foam structure after the bubble walls have completely polymerized and solidified. See **cell; foam and process cell structure; nucleating agent, cell-control.**

foamed cell, closed A cell that is enclosed by a membrane and rib structure.

foamed-cell collapse Inadvertent densification of foam during fabrication that results from the breakdown of cell structure.

foamed cell, open A cell that interconnects within a riblike structure (skeletal). A noninterconnecting cell structure also exists. Also called *reticulated* or *weblike material.*

foamed cell unit See **cell unit.**

foamed chemical blowing agent See **foam and blowing agent.**

foamed, coextruded See **blow molding coextrusion foam; coextrusion.**

foamed, cold-cure A method that is used to produce high-resiliency flexible foams.

foamed compound, polyol See **reaction injection molding.**

foamed concrete See **cellular concrete.**

foamed core See **core, honeycomb or foam; sandwich construction.**

foamed cream time The length of time between pouring mixed foam, usually PUR, and when the material turns creamy or the beginning of foaming. See **foamed rise time.**

foamed cure time The time at which the chemical reaction is 100% complete and all desired physical properties are achieved.

foamed density, reduced The reduction in the weight of plastics such as the ratio of foam bulk density to nonfoamed (processed solid) bulk density.

foamed elastomer A cured elastomeric material that contains variations of cells or small voids that can provide different degrees of flexible to rigid foamed plastics. See **elastomer.**

foamed, expandable plastic See **expandable plastic.**

foamed, expandable polystyrene See **expandable polystyrene.**

foamed, extruded See **extruder cooling and take-off equipment; coextrusion foam core.**

foamed flame resistant coating See **coating; intumescent.**

foamed free rise The unrestricted rise of a foam.

foamed frothing Blowing agent or tiny air bubbles under pressure into a liquid mixture of foam ingredients. The foam is permanently stabilized by chemical reactions.

foamed ground aircraft arrester A bed system of closed cells, rigid phenolic foamed sheets that can be arrayed in an airport overrun or safety area of an airport runway. This safety approach is designed to slow and stop airliners that overrun runways. The foam is designed to crush under the aircraft's landing gear, creating a sufficient drag to stop the plane safely.

foamed house See **plastic house.**

foamed, injection-molding See **injection molding, foamed gas counterpressure.**

foamed in place Having foam deposited when a foaming machine or filled canister is brought to the work as opposed to the work brought to a foaming machine. The technique involves depositing a foamable plastic (prior to it being foamed) into the place where it is intended that foaming will take place. After insertion, foaming action occurs. Thus a foamed insulation can be poured in buildings, packages, and so on. Also called *in-situ*. See **foamed polyurethane.**

foamed latex See **latex foam.**

foamed, one-shot system PUR foam, in which none of the isocyanate portion has been prereacted with any portion of the polyol prior to final mixing. See **foamed, prepolymer; reaction injection molding.**

foamed-peak rise point The highest rise that a foam may achieve prior to the occurrence of cell rupturing and thereafter settling.

foamed peanut See **packaging, loose-fill plastic.**

foamed-plastic market Nearly all markets use foamed plastic. A guide to consumption by weight is insulation 24%, packaging 18%, cushioning 15%, transportation 12%, furniture 6%, flooring 6%, consumer 4%, bedding 4%, appliance 2%, and other 9%.

foamed plastic, mechanical A cellular plastic that has a structure produced by physically incorporating gases. See **foam.**

foamed plastisol See **plastisol, modified.**

foamed polyethylene ionization Process of foaming PE by exposing it to ionizing radiation that evolves hydrogen from the PE causing it to foam. See **ionization.**

foamed polystyrene See **expandable polystyrene.**

foamed polyurethane Liquid (pour-in-place), froth (modified pour-in-place), and spray foaming techniques are examples of different methods used with PUR foaming. When the liquid ingredients are mixed, gases are produced that cause the mass to expand at the same time as it stiffens and hardens. The reaction is complete in a few minutes. For example, in a sandwich structure, the liquid mix is poured between the cover sheets or skins and foams between them. Bonding is directly to the sheets. As foamed-in-place materials expand, they can exert appreciable pressure so that the sandwich sheets have to be held in a rigid frame to prevent bulging until the reaction is completed. To overcome this pressure, the liquid mix can be allowed to form a froth of almost its ultimate volume prior to pouring. The result is little or no pressure, and rigid foam is produced. This two-step or prepolymer blowing action is considered a variation of the conventional foam-in-place method.

Flexible PUR foam, which is used in upholstery, is made by continuous deposition on a conveyor belt. Then it is cut into blocks or sheets of desired shape and size. The component-forming blowing agent in PUR's soft, flexible-foam formulation is water, which forms carbon dioxide with the isocyanates. The heat and evolution of temperature resulting from this gas-generated reaction, however, necessitate additional use of other blowing agents (such as diechloromethane) that are used at the same time as coolants in the production of low-density foam of less than 20 kg/m^3. Flexible PUR foams have open cells and are extensively used (sponges, sealants, insulations, packaging, furniture, automotive, etc.).

A rigid, foamed cross-linked PUR, usually with closed cells, is formed by the reaction of a diisocyanate and often MDI (methane diisocyanate) or polymeric MDI with polyester or more usually with a polyether polyol. Foaming may result from the incorporation of water that reacts with the isocyanate groups to form carbon dioxide. Usually it is the result of using other blowing agents sometimes in combination with water. They become rigid compared to flexible foams by being more heavily cross-linked. This is accomplished by the use of polyols, usually polyoxypropylene glycols of low molecular weight (about 500), which are highly branched by mixing the higher functionality comonomers (such as sorbitol or pentaerythritol). Prepolymer processes and quasi-prepolymer processes are used with TDI (toluene diisocyanate) to reduce the toxic hazard of this material. One-shot processes are used with MDI and polymer MDI with polyether; normally a tertiary amine or organotin catalyst system is used, together with a silicone surfactant as with flexible foams. Catalysts are usually also used to give the right balance of reaction rates so that the gas bubbles are trapped in the liquid paste melt as the viscosity increases due to polymerization and cross-linking. The major application for these foams is for insulation as they have exceptionally low thermal conductivity. See **air atomization; catalyst; coating, air atomization; coating, centrifugal atomization; cross-linking; foamed in place; hazard; polymerization; polyurethane plastic; sandwich core material.**

foamed, prepolymer A polyurethane system where a portion of the polyol is prereacted with the isocyanate to form a liquid prepolymer with a viscosity range suitable for pumping or metering. This component is supplied to the end-users with a second premixed blend of additional polyol, catalyst, blowing agent, and so on. When the two components (two-shot) are mixed, foaming occurs. See **foamed, one-shot system.**

foamed pressure test See **test, foam pressure.**

foamed reservoir molding A sandwich of plastic-impregnated open-celled flexible PUR foam that is positioned between the face layers of fibrous reinforcements. When heated in a mold and squeezed, the foam is compressed, forcing the plastic and air outward and into the reinforcement contacting the mold cavity. Also called *elastic reservoir molding.*

foamed rise time The time when the materials have been mixed and dispensed to the time when volumetric expansion ceases; foaming is completed. See **foamed cream time.**

foamed self-skinning A tough outer surface skin over a foamed core that is produced on curing. It can meet different requirements such as being decorative, tough or strong, and having a relatively lower density core. Also called *integral skin foam.* See **injection molding, foamed gas counterpressure.**

foamed sheet stock Expandable sheet (or film) stock that is produced by different methods such as calendering. Also called *bun.* See **foamed bun; expandable polystyrene block molding.**

foamed sponge See **cellulose sponge; foam.**

foamed spray-up Fast-reacting foamed plastics, such as polyurethane and epoxy, are fed in liquid streams to a spray gun and sprayed onto a surface. On contact, the liquid starts to foam until solidified.

foamed two-shot system See **foamed, prepolymer.**

foaming agent See **foam and blowing agent.**

foaming, anti- See **antifoaming agent.**

foaming, coextruded See **blow-molding coextrusion foam; coextrusion foam core.**

foaming cycle time See **test, foam pressure.**

foaming, in-situ See **foamed in place.**

foam inverse lamination The ICI rigid-faced polyurethane laminate process. Inverse lamination starts as lay-down carrier paper (flexible facing) receives urethane chemicals from a mixing head. It travels between floating platens supported by conveyor belts sandwiching the controlled expanding foam. The adjustable lay-down gap between belts permits coating with thinner or thicker foam or in a faster or slower formulation. Foam forms on the flexible facing as it moves around a heated platen just prior to going between the belts. The inverted foam bonds to a rigid facing as it moves and cures under the floating platens to the end of the line where it is trimmed and cut. See **coating.**

foam, microcellular Extruded foam sheet, such as polystyrene, with densities of 0.035 to 0.1 g/cc (2 to 6 pcf) and uniform closed cells measuring less than 50 microns.

foam molding See **foam, structural.**

foam molding, reactive polymer See **polymer, reactive.**

foam molding, two-stage See **foamed, prepolymer.**

foam, physical blowing agent See **foam and blowing agent.**

foam pressure See **test, foam pressure.**

foam, reinforced Thermoplastic and thermoset plastic foam that is reinforced usually with short glass fibers. The fibers are generally introduced into the basic ingredients prior to foaming. They reinforce the walls of the cells. With fiber content up to 50wt% using thermoset plastics, mechanical properties can be increased 400 to 500%. Gains also occur with thermoplastics but are not as significant. Other advantages in addition to strength and stiffness with reinforcements include improved dimensional stability, resistance to extremes of temperature, and resistance to creep. See **foamed reservoir molding; reinforcement; reinforced-plastic syntactic cellular plastic.**

foam, structural (SF) A foam that is characterized by near-uniform-density foam core and integral near-solid skins. Major process is in low-pressure injection molding, which consumes about 75wt%, with RIM and extrusion also used. Also called *integral-skin foam-reaction injection molding.* See **injection molding, foamed gas counterpressure; molding, structural-web; reaction injection molding; structure, secondary.**

foam, syntactic See **reinforced-plastic syntactic cellular plastic.**

foam testing See **test, foam pressure.**

fogging See **antifogging agent.**

foil A very thin sheet of material, such as aluminum foil. See **aluminum foil.**

foil decorating Plastic, paper, and fabrics are printed with inks that are compatible to the plastics that will be used in the fabrication of decorative surfaces. The foil can be visible below the surface as an integral decoration. In-mold decorating is used where the foil can be located in a mold prior to having the plastic fill the mold so that it becomes an integral part of the molded part. Other fabricating processes incorporate foil. See **aluminum foil;**

decorating; injection molding, in-mold, decorating; laminate, decorative.

fold, accordion Two or more parallel folds that open like an accordion.

fold, dead A fold that does not spontaneously unfold.

fold, right angle Two or more folds that are at 90° angles to each other.

Follow ALL Opportunities See **FALLO approach.**

food molding See **injection molding nonplastics.**

food packaging See **packaging, food.**

food taste test See **test, organoleptic.**

food waste See **landfill and degradation.**

force The force, load, or pressure that changes the state of rest or motion in matter. See **equilibrium; G-force; load; test, microdynamometer; test, force-extension; tear resistance, initial; weight.**

forecasting See **statistical forecasting.**

forensic science and plastic See **legal matter: forensic science and plastic.**

forging A production method in which usually heated thermoplastic stock or billet material (plastics, steels, etc.) is shaped to a desired form (rods, bars, H-beam, etc.) by compression forces or by sharp hammerlike blows. Virtually all ductile materials may be forged, and in some cases preheating is not required. Forging below the melt temperature is called *cold forging;* with plastics it can also be called *cold forming* or *solid-phase pressure forming.* When worked above the melt temperature, it is said to be *hot forging* or *hot forming.* Also called *impression molding.* See **forming; material, billet; thermoforming.**

formable laminate See **laminate, high-pressure formable.**

form, fill, and seal See **blow molding, extruder blow, fill, and seal; medical packaging; thermoforming, form, fill, and seal.**

forming The shaping of thermoplastic stock or billet plastics to produce a wide variety of marketable products in a wide size range. Different techniques are used, with thermoforming being the most important and the most diversified. Other techniques are similar to thermoforming but usually use less heat and are more limited to the plastic used. These processes include cold forming or forging, postforming, stamping, scrapless forming, and so on. See **design hinge, integral; draw; postforming; thermoforming.**

forming blank See **blank.**

forming cake See **filament-winding cake forming.**

forming, cold A process of changing the shape of primarily thermoplastic sheet, film, or billet in a solid phase through plastic (permanent) deformation with the use of pressure dies. The process can include heating that is usually well below the plastic's melt or thermoforming temperature. Thermoset plastics such as B-stage can be used. Most metal-forming techniques—such as stamping, drawing, forging, coining, and rolling—are used on plastics. The main difference between metal and plastic forming is the time dependency or spring-back, or recovery in thermoplastics. All materials exhibit some strain recovery or spring-back. With thermoplastics this process depends on temperature, time, and deformation history. For any given forming temperature, holding the part in the deformed state for a given period to allow for stress relaxation reduces the degree and rate of spring-back. See **forging; forming, solid-phase pressure.**

forming, cold-drawing A stretching or orientation process that is used to improve properties, such as tensile strength and modulus of thermoplastic film, sheet, or filament by orientation of molecules. Also called *cold stretching.* See **brittle failure; filament; orientation.**

forming, compression-stretch See **blow molding, compression-stretched.**

forming, dip A process that is similar to dip coating except that the fused, cured, or dried deposit is stripped from the dipping form, mold, or mandrel. It is most frequently used for making vinyl plastisol products. The process can be manual or completely automated and involves (1) a container or tank with a liquid plastic such as a plastisol, (2) a preheated form, shaped to the desired inside dimensions of the finished product, (3) a dip into the plastic for a prescribed time so that the plastic gels against the form to the desired thickness (coatings are limited to a maximum thickness based on plastic used, heat in the form, and the time cycle), (4) withdrawal of the coated form and usually a final heat to complete the fusing, (5) cooling, and (6) stripping the coating off the form. Also called *dip molding.* See **coating, dip; plastisol.**

forming, post- See **postforming.**

forming, rubber-pad Forming that is similar to matched-metal stamping except that one of the metal dies is replaced by a block of solid rubber. Processing material cannot flow to the extent that it can with matched-metal die stamping. However, more uniform pressure is exerted on the material charge. Also called *rubber molding* or *rubber stamping.*

forming, scrapless A specialty solid-phase forming (SPF) technique patented by Dow Chemical. It is a relatively simple process. An extruder or extruders produce a biaxially oriented sheet. The sheet is slit and cut into square blanks. These blanks are heated and pressed into circular disc with a lip. Immediately or later, after reheating, the disc is thermoformed into a shape such as a cup. See **blow molding, compression-stretched; blow molding, injection; blow molding, innovative; blow molding, stretched operation specialty; orientation, biaxial; thermoforming.**

forming, slip A sheet-forming technique in which some of the plastic sheet material is allowed to slip through mechanically operated clamping rings during stretch-forming operations. See **orientation; thermoforming, slip.**

forming, solid phase A technique in which a sheet or block of plastic is reshaped under heat and pressure.

However, the forming temperature is below the melting temperature of the plastic. See **thermoforming, solid-phase pressure.**

forming, solid-phase pressure Dow Chemical started with a patented solid-phase forming (SPF) process and extended it to special multilayer structures called coforming (COFO). COFO maintains the advantages of SPF, most significantly biaxial orientation. The blank, cut from sheet, compression molded, or compacted from powder, is heated above its softening point but below its melting point. Forging the blank into a preform between a heated anvil follows. The blank is forced into a set of cooled lip rings that mold the peripheral configuration of the part (such as a cup). Clamped by these clip rings, the preform is then plug-assist pressure-formed against a cold mold. Parts with depth-of-draw ratios from 0.25 to 1.3, both round and rectangular, can be formed. See **compression molding; forming, scrapless; thermoforming, pressure; thermoforming, solid-phase pressure.**

forming, stretch The process of stretching a thermoplastic to reduce its cross-sectional area. It provides a means of creating a more orderly arrangement of a plastic's molecular chains molding; stamping with respect to each other. Also called *drawing.* See **orientation.**

forming, stretch and draw ratios for pressure The ratio of the surface of the formed part to the net starting area of the original sheet. An average stretch ratio is 3 to 1 for pressure forming. The draw ratio is the maximum depth of the forming mold to the minimum distance across the open face at any given location on the mold; the usual draw ratio is 1 to 1. See **thermoforming, pressure.**

forming, superplastic (SPF) A strain-rate-sensitive forming process that uses characteristics of materials exhibiting high elongation to failure. See **elongation; strain.**

forming, superplastic/diffusion bonding process The combination of superplastic forming with isotactic molding that permits the molding of complex reinforced-plastic parts. See **molding, isotactic.**

formula **1.** The materials and their amounts that are used in preparation of a compound. See **recipe. 2.** A combination of chemical symbols that expresses a molecule's composition. See **chemical formula. 3.** A reaction formula showing the interrelationship between reactants and products. **4.** See **design, basics-of-flow die; formula; ionic equation, net; mathematical equation.**

formula, empirical A chemical formula that indicates the variety and relative proportions of the atoms in a molecule but does not show the manner in which they are linked together.

FORTRAN software This FORmula TRANslation language is a widely used high-level computer programming language well suited to problems that cannot be expressed in terms of algebraic formulas. It is generally used in scientific applications. See **computer software.**

fouling coating See **coating, antifouling.**

foundry plastic A plastic that is used in different casting techniques. Included are plastic-based binders mixed with sand. Various types of molds and cores are produced that include no-bake or cold-box, hot-box, shell, and oven-cured. The usual binders are phenolic, furan, and thermoset polyester.

foundry shell molding A type of molding process that is used in the foundry industry, in which a mixture of sand and plastic (phenolic, thermoset polyester, etc.) is placed onto a preheated metal pattern (producing half a mold) causing the plastic to flow and build a thin shell over the pattern. Liquid-plastic precoated sand is also used. After a short cure time at high temperature, the mold is stripped from its pattern and combined with a similar part produced by the same technique. The finished mold is then ready to receive the molten metal. Blowing a liquid plastic and sand mix in a core-box also produces shell molds. Also called *dry-mix molding.* See **blow molding.**

fountain flow, melt See **mold-cavity melt fountain flow.**

fourdrinier The machine that is most widely used for papermaking. It uses plastic fibers to produce plastic papers or nonwoven fabrics. See **deckle rod; fabric, nonwoven mechanical; fiber carding; paper.**

Fourier's infrared transfer See **spectroscopy, Fourier's transfer infrared.**

Fourier's law See **devolatilization.**

fraction See **distillation, fraction.**

fracture A crack. The fracture behavior of plastics, especially microscopically brittle plastics, is governed by the microscopic mechanisms operating in a heterogeneous zone at their crack or stress tip because of internal or external forces. In thermoplastics, craze zones can develop that are important microscopic features around a crack tip governing strength behavior. Fracture is preceded by the formation of a craze zone, which is a wedge-shaped region spanned by oriented microfilms. Methods of craze-zone measurements include optical emission spectroscopy, diffraction techniques, scanning electron-beam microscopy, and transmission electron microscopy. See **brittle failure; crack; ductility; failure; test analysis, micromechanical.**

fracture, brittle A fracture without plastic (any material behavior) deformation, hence with little energy absorption, that follows the Griffith theory. See **design-failure theory, Griffith.**

fracture ductility The true strain of fracture in a material. See **strain.**

fracture mechanic See **crack growth.**

fracture strength True stress at the start of fracture based on the load applied at the beginning of the fracture during a tension test and the original cross-sectional area of the specimen. See **stress.**

fracture stress See **stress, fracture.**

fracture toughness A measure of damage tolerance of a material containing initial flaws or cracks.

fragrance concentrate Preformed free-flowing pellets

or powder. See **colorant; deodorant additive; odorant agent.**
free extrusion See **extruder, free.**
free trade See **legal matter: free trade.**
freeze-dry color See **color, freeze-dry.**
freeze layer See **mold cavity, frozen-layer.**
freeze line See **extruded-blown-film frost line.**
freeze, melt See **mold gate, valve; temperature, freeze.**
freeze-off The melt that should not freeze during fabrication, such as during extrusion or injection molding. Melt solidification can occur in different locations such as in an extruder motionless mixer or die orifice restrictions. With IM, freezing can occur in the nozzle, runner, gate, and so on. See **mold cavity, frozen-layer.**
French mold See **mold, French.**
frequency The number of cycles that are completed or required in a unit of time. See **attenuation; period.**
frequency bandwidth The range of frequencies within which performance of a component is accurate, usually extending from zero frequency to some cutoff frequency.
frequency, natural undamped The frequency of free vibrations resulting from only elastic and inertial forces of a mechanical system. See **damping gamma loss peak.**
frequency, resonant See **resonant frequency.**
Fresnel diffraction pattern The pattern that occurs when the radiation intensity at any point is the result of disturbances coming directly to the point from all parts of the exposed wave-front. The point at which the diffraction pattern is observed is at a relatively small distance from the diffracting element, as in contact printing.
Fresnel lens A transparent material into which grooves have been formed into desired patterns so that light will be focused as with convention lens. See **transparent; weatherability.**
frettage The surface damages that are caused by small movements between mating surfaces as in a press fit. With an oscillation motion, an abrasive action occurs, causing more damage. Also called *fretting erosion* or *false brinelling.* See **wear.**
friction The opposing force that develops when two surfaces move relative to each other. The two frictional properties that are exhibited by any surface are static friction and kinetic friction. See **abrasion; antifriction compound; coefficient of friction; coefficient of friction, static; design lubricant, reduced-friction; kinetic friction; welding, friction.**
frictional coating See **calendering coating, frictional.**
friction, Coulombic The opposing force that occurs when two dry surfaces are rubbed together, as in vibration and spin welding. Also called *external friction.*
friction, internal The conversion of mechanical strain energy to heat in a material exposed to a fluctuating stress.
friction ratio The ratio of surface speeds of two adjacent rolls (calender, mill, extruder coating, etc.).
friction welding See **welding, friction; welding, spin.**
frit A glass that contains fluxing material and is employed principally as a constituent in a glaze such as porcelain enamels or other ceramic composition. Frit is also used as filler.
frosting A light-scattering surface resembling fine crystals. See **bloom; chalking; haze.**
frost line See **extruded-blown-film frost line.**
frothing See **foamed frothing.**
frozen food container See **packaging, dual-ovenable tray.**
frozen-in stress See **adhesive, solvent; orientation, accidental; stress, frozen-in.**
frozen strain See **strain, residual.**
fuel consumption See **energy consumption.**
fuel, refuse-derived See **refuse-derived fuel.**
fuel tank See **gasoline tank permeability.**
fuller's earth A porous colloidal aluminum silicate (clay) that has high natural adsorptive power and is noncombustible and gray to yellow color. It is used as an elastomer plastic filler. See **filler.**
full indicator movement See **tolerance, full-indicator-movement.**
fume An unpleasant, irritating odor that requires ventilation and that is caused by degrading melt. This occurs because plastics have high specific heat and low thermal stability.
fume cleanup See **incineration fume system.**
functional group See **atom functional group.**
functional plastic See **plastic, smart.**
fundamental processing See **processing fundamental.**
fungicide additive An agent that inhibits the germination of fungus spores or their metabolic products. See **biocide; cupric oxide.**
furan plastic A dark liquid thermoset plastic in which the furan ring is an integral part of the plastic chain. It is made by the condensation of furfuryl alcohol. It is primarily used as liquids ranging from low viscosity to thick, heavy syrup-type plastics. It is used as an adhesive, a casting plastic, a coating, and an impregnant.
furfural plastic A dark colored thermoset plastic that is used in the manufacture of molding compounds, adhesives, and varnishes. Its properties include high resistance to acids and alkalies.
furnace black A carbon black that is formed by partial combustion of liquid and gaseous hydrocarbons in a closed furnace with a deficiency of oxygen. It is used as a reinforcing filler for plastics and rubbers.
furnace, blast A vertical coke-fired furnace that is used principally for smelting metallic ores to produce iron ore.
furnace, facial protective heat shield See **allyl diglycol carbonate plastic.**
furnace, muffle See **muffle furnace.**
furniture market Plastic office furniture—principally chairs, panels, and laminates for desks—represents about

a $10 billion market or just 3½wt% of plastics. Unreinforced and glass-reinforced PPs are principally used. Lawn and garden furniture consumes about 2½wt% plastics, also principally PPs; about 3wt% is used with metal. All these products as well as others have a good growth rate. See **automotive seat; market; nail.**

furniture web See **orientation and heat-shrinkability.**

fusible Capable of being melted and formed by heat. See **heat.**

fusible-core process See **soluble-core molding.**

fusion **1.** In vinyl dispersion, the heating of a dispersion to produce a homogeneous mixture. See **plastisol. 2.** The process of melting. See **calcining; coating, sinter; powder coating; welding, fusion. 3.** An endothermic nuclear reaction that yields large amounts of energy in which the nuclei of light atoms unite or fuse to form helium. **4.** See **coating, Engel process; joining, butt-fusion; seal; welding, fusion; welding, hot-tool. 5.** See **molar heat of fusion.**

fusion Kling test See **test, fusion Kling.**

future, plastic See **plastic growth; plastics and the future.**

fuzz, fiber See **fiber fuzz.**

fuzzy logic control See **control, fuzzy-logic; temperature controller.**

G

GAIM software (gas-assisted injection-molding software) A software developed by Advanced CAE Technology Inc., Ithaca, NY, that helps the user overcome lack of experience with the gas-assisted injection-molding by process evaluating alternative designs and determining the best processing conditions. See **computer software; injection molding, gas-assist.**
galling The wearing away of surfaces when they rub against each other. See **wear.**
galvanized steel See **iron; recycling steel with vinyl scrap.**
gamma radiation Ionizing radiation that is propagated by high-energy protons, such as that emitted by a nucleus in transition between two energy levels. See **cobalt-60; lead; radiation.**
gamma-ray analysis See **test, nondestructive-radiography.**
gamma transition See **glass transition.**
gap-filling See **adhesive gap-filling.**
garbage in, garbage out (GIGO) A phrase that means that putting in invalid data produces invalid results. See **test, Gardner impact.**
gas A mixture of low- and high-molecular-weight hydrocarbons that provide basic raw materials to produce plastics. See **cracking; oil and gas; oil, cracking; oil, crude.**
gas adsorber See **pollution, air; scrubber.**
gas analysis, residual (RGA) The study of residual gases in a vacuum system using mass spectrometry.
gas-assist molding See **injection molding, gas-assist.**
gas, black See **carbon black.**
gas burn A burn that is caused by gases that are trapped during processing when plastic melt fills the mold cavity faster than the gasses can escape through a venting system. etc. Pressure build-up of the entrapped air causes the burning. See **colorimetry, visual; scrubber.**
gas chromatography See **chromatography, gas; vapor detector, dielectric.**
gas consumption See **energy consumption.**
gas contamination See **outgassing.**
gas counterpressure molding See **injection molding, foamed-gas counterpressure.**
gas cure See **extruder wire and cable.**
gas effusion A process by which a gas, under pressure, escapes from one compartment of a container to another by passing through a small opening.
gas-fired catalytic heater See **heating-catalytic.**
gasification A process for chemically recycling plastics. Processes are run with an atmosphere of oxygen and steam at 900 to 1,400°C, under 0 to 60 bar pressure, to produce mostly carbon monoxide and hydrogen. See **recycling, chemical.**
gas injection molding See **injection molding, gas-assist.**
gasket A mechanically deformable material that is clamped between essentially stationary faces to prevent the passage of matter through an opening or joint. See **compressibility; creep; packing.**
gas leakage test See **test, soap-bubble.**
gasoline tanks Automotive blow-molded gasoline fuel tanks have been in use since at least the 1940s in U.S. military vehicles and European autos. The United States gradually started using monolayer high-density polyethylene, chemically treated to create a barrier (sulfonation or fluorination) on the inside, which provided essentially gasoline emission-free containers that met the standards of that era. By the 1960s three-layer tanks that included a barrier layer of ethylene-vinyl alcohol copolymer or nylon between HDPE also were used. Then came the six-layer tanks with HDPE skins and inside layers that included reground HDPE and EVOH. See **barrier; blow molding; coefficient of permeability; coextrusion; fluorination; sulfonation; thermoforming.**
gas, pentane See **pentane gas.**
gas, permeability, coefficient See **coefficient of gas permeability.**
gas-phase polymerization See **polymerization, gas-phase.**
gas plasma See **sterilization, gas plasma.**
gas pocket A pocket of unwanted gas or air that is entrapped in a plastic during processing.
gas pressure and temperature According to Boyle's law, the volume of a sample of gas varies inversely with the pressure if the temperature remains constant. This law is satisfactory for practical calculations except when pressures are high or temperatures are approaching the liquefaction point. Van der Waal's equation is a refinement that takes care of the inherent inaccuracy of Boyle's law. See **Avogadro's law; kinetic theory; temperature; van der Waals force.**
gassing See **mold breathing.**
gas transmission See **test, permeability.**
Gatterman reaction See **chemical reaction, Gatterman.**
gauge A measuring instrument that is used to determine if a part meets product requirements. Examples include micrometers, calipers, mechanical guides, and electronic devices (color matching, dimensions, etc.). See **sensor; sensor, beta gauge; strain gauge.**
gauge length The known distance between bench marks.

Gaussian distribution See **statistical normal curve.**
gaylord See **material handling, manual; storage.**
GDP See **gross domestic product.**
gear Plastics, particularly acetal and nylon plastics, have been extensively used in gears including gears used as replacements for metal gears. Converting metal gears to plastic gears presents a host of benefits, among them lighter weight, lower noise, chemical resistance, and lower cost. They are used in all industries, such as business equipment, appliances, automotive auxiliaries, and consumer goods. See **backlash.**
gear box See **extruder gear box; fabricating output.**
gear pump The pump has been standard equipment for over a half century in textile fiber production. During the 1980s it was established in all kinds of extrusion and injection molding lines. The device consists of a pump, a drive for the pump, and pump controls located between the screen pack (or screw) and die. Two counterrotating gears transport a melt from the pump inlet (extruder output) to the pump discharge outlet. Gear rotation creates a suction that draws the melt into a gap between one tooth and the next. This continuation action from tooth to tooth develops a surface drag that resists flow, so some inlet pressure is required to fill the cavity. This pump device is basically a closely intermeshing, counterrotating, twin-screw extruder. However, since gear pumps are solely used to generate pressure, they are seldom called extruders, even though they are extruders. See **extruder melt-flow oscillation; fiber filtration; fiber processing.**
gear pump pressure The inlet pressure requirements vary with material viscosity, pump speed, and mixing requirements. These pressures are usually less than 1,000 psi (69 MPa) but cannot go below specified pressures such as 300 psi (21 MPa). An extruder specifically designed for use with a pump needs only to mix and does not need to operate at high pressures to move the melt. It only has to generate the low pump-inlet pressure; thus it can deliver melt at a lower than usual heat, requiring less energy and often yielding a higher output rate. This positive displacement gear device pumps the melt at a constant rate. It delivers the melt to the die with a very high metering accuracy and efficiency. It is common to have pressure differentials as high 4,000 psi (276 MPa) between pump inlet and discharge. Also called *melt* or *metering pump.*
gear ratio See **fabricating output.**
gel **1.** The initial jellylike solid phase that develops during the formation of a plastic from a liquid. It usually causes a defect in the processed plastic. It is soft, flexible, and may rupture under its own weight unless supported externally. Its processing characteristics differ from the surrounding plastic to such a degree that it is not easily dispersed. It is a semisolid that can consist of a network of solid aggregates in which liquid is held. Also called *gelatinous mass.* See **antigelling agent; extruder gel; pectin. 2.** The stage at which a polymerized plastic composition thickens to a semisolid state. It is a two-phase colloidal system consisting of a solid and a liquid in more solid form than a sol. See **aerogel; plastigel. 3.** In vinyl plastisols, a state between liquid and solid that occurs in the initial stages of heating or on prolonged storage. **4.** In a cross-linked thermoplastic, the fraction of polymeric material present in the cross-linked network. **5.** See **dendritic plastic; electrophoresis; polyacrylamide plastic; silica.**
gel and air See **aerogel.**
gel, anti- See **antigelling agent.**
gelatin **1.** The formation of a gel. **2.** In vinyl dispersions, the formation of gel in the early stages of fusion.
gelation The point in a plastic cure, such as a thermoset plastic, when the plastic viscosity has increased so that it barely moves when probed with a sharp instrument. The formation of infinitely large plastic networks in the reaction mixture. See **plastisol.** Gelations can be derived from collagen, the primary protein component of animal connective tissues, such as bone, skin, and tendon.
gelation time The time from the introduction of a catalyst into a liquid thermoset plastic adhesive until the start of gel formation.
gel coating See **reinforced-plastic gel coat.**
gel, hydro- See **hydrogel.**
gel, irreversible A gel that, when added to the evaporated liquid, does not give back a jelly (colloidal silica).
gel, latex See **latex gel.**
gelled See **polyvinyl chlorides, plastic gelled.**
gelling additive See **thickening agent.**
gelling, anti- See **antigelling agent.**
gel, micro- A small particle, about 100 nm, of cross-linked and insoluble plastic that may be considered to be a single molecule. With its molecular dimensions, it can dissolve in solvents to give a true solution. Gels can embrittle and reduce the tensile strength of plastics but may be beneficial, such as in having a smoothing action in extrusion of elastomers.
Geloy GE Plastics' trade name for its family of weatherable plastics.
gel, pectin A water-soluble carbohydrate substance that is found in the cell walls and intercellular tissues of certain plants. It has the ability to gel.
gel permeation chromatograph See **chromatograph, gel permeation.**
gel, plastic See **plastigel.**
gel, pre- See **reinforced-plastic pregel.**
gel point The stage at which a liquid begins to exhibit elastic properties and increased viscosity. For example, it is the point at which a thermoset plastic reaches an infinite value of its average molecular weight. Its liquid viscosity begins to exhibit pseudoelastic properties. This behavior can be observed from the inflection on a viscosity-time curve. See **liquifier.**
gel polymerization effect See **polymerization, free-radical.**
gel, rubber The portion of rubber that is insoluble in a chosen solvent.

gel spinning process See **fiber processing, gel-spinning.**
gel, syneresis The contraction of a gel that is accompanied by the separation of a liquid.
gel time The time in which a reaction mixture forms a gel under specific temperature conditions.
gel, zero- A gel that has dried until apparently solid. Sometimes it will swell or redisperse to form a solid when treated with a suitable solvent.
general purpose See **plastic, general-purpose.**
generic A class of plastics that use one base plastic. A few hundred base plastics, worldwide, are used to produce about 17,000 different plastics. A base plastic is compounded in many different ways with different alloying methods. The many different additives, fillers, and reinforcements result in plastics that meet various processing capabilities. See **compounding; plastic material type.**
geodesic See **design, geodesic.**
geogrid A relatively rigid latticelike fabric that is especially useful in reinforcement structures. See **geotextile.**
geomembrane A liner that provides an impermeable barrier. Geomembranes are used in (1) solid-waste containment (hazardous landfill, landfill capping, and sanitary landfill), (2) liquid containment (canal, chemical/brine pond, earthen dam, fish farm, river/coastal bank, wastewater, and recreation), (3) mining, leach pad, and tailing ponds, and (4) specialties (floating reservoir caps, secondary containment, tunnel, erosion, vapor barrier, and water purification). Plastics that are used include medium- to very low-density PE, PVC, and chlorosulfonated PE (CSPE). The Romans used in their land and road constructions what we call geomembrane. See **geotextile; landfill and degradation; pollution; toxicity; waste.**
geometric dimensioning See **dimensioning and tolerancing, geometric; screw transition zone, conical and involute.**
geometric metamerism See **light metamerism.**
geometric modeling See **computer-aided design; computerized knowledge-based engineering.**
geometric steradian The solid angle that has its vertex in the center of a sphere and cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere. See **candela.**
geometry The branch of mathematics that deals with the measurement, properties, and relations of points, angles, surfaces, and solids. See **asymmetric; asymptote.**
geometry, joining See **joining geometry.**
geothermal pipe See **pipe, geothermal.**
genotoxicity See **test, carcinogenicity.**
Geon Geon Co.'s trade name for its family of PVC plastics.
geoscience The science that deals with the earth.
geosynthetic Pertaining to synthetic materials, such as plastics, that are used with the earth.
geotextile Geotextiles, as well as geonets, geogrids, and geomembranes, represent a major market for plastics. They appear in all manners of civil works, from roads to canals, from landfills to landscaping. They often prove more cost-effective than natural and other synthetic products. The primary plastics are polyester, nylon, polypropylene, and HDPE filaments. The fabrics are made in both woven and nonwoven varieties. The former are characterized by high-tensile, high-modulus, and low-elongation traits; the latter by high permeability and high elongation. Also called *geosynthetic.* See **geomembrane; fabric, nonwoven; fabric, woven; landfill and degradation.** It is the condition where soil particles move into and are retained in the openings of a fabric, thereby reducing hydraulic conductivity.
G-fiber See **fiberglass type.**
G-force The measure of the gravitational pull of the earth as modified by the earth's rotation, equal to the acceleration of a freely moving body at the rate of 32.16 ft/s/s.
Gibbs indophenol See **test, phenol Gibbs indophenol.**
gilsonite A black substance, resembling asphalt, that is used as an ingredient in the manufacture of cold-molding compounds, paints, and so on.
glass An inorganic product of fusion that has cooled to a rigid condition without crystallizing. Glass is typically hard and relatively brittle and has a conchoidal fracture. It contains the most abundant elements of the earth—sand. Although basically a ceramic product, glass is an amorphous inorganic plastic. Glass is always used in its elastic range and below its glass transition temperature (T_g). See **fiberglass; plastic, light-switchable.**
glass blowing See **blowing glass; blow-molding glass, press and blow process.**
glass, borate A glass in which the essential glass former is boron oxide instead of silica
glass cloth Woven glass-fiber material. See **fabric, woven.**
glass composition Most glass is based on the silicate system and is made from the three major constituents of silica (SiO), lime ($CaCO_3$), and sodium carbonate ($NaCO_3$). Various oxides are added to tailor the glass to meet specific requirements. Families of glass include soda-lime (windows, bottles, drinking glasses, etc.), borosilicate (thermal and chemical shock resistant), lead-alkali (optical applications, better electrical), aluminosilicate (high operating heat), silica (formable), and fused silica (high properties, expensive). See **fiberglass type; lead; lime.**
glass cullet See **cullet.**
glass devitrified Glass with controlled crystallization.
glass fiber See **fiberglass.**
glass-filament liquid temperature The maximum temperature at which equilibrium exists between the molten glass during its manufacture and its primary crystalline phase.
glass filler A widely used family of fillers that includes beads, hollow spheres, flakes, and milled particles. Fillers increase dimensional stability, chemical resistance, mois-

ture resistance, and the thermal stability of the plastic matrix. See **filler.**

glass finish See **fiber finish.**

glass flake A thin, irregularly shaped flake of glass that is used as reinforcement. See **attenuation; flake.**

glass formation See **designing with plastic-chemical models.**

glass former An oxide that forms glass easily and contributes to the network of silica glass when added to it.

glassine A thin, transparent, and very flexible paper obtained by the excessive beating of wood pulp. It may contain an admixture such as urea-formaldehyde plastic to improve strength. See **urea formaldehyde plastic.**

glassiness See **reinforced-plastic glassiness.**

glass liquidus temperature The maximum temperature at which equilibrium exists between the molten glass and its primary crystalline phase.

glass mat See **fiber mat.**

glass microsphere See **microsphere.**

glass mirror plating See **plating, silver spray.**

glass-plastic alloy See **plastic-glass alloy.**

glass-plastic laminate See **polyvinyl butyral plastic; safety glass.**

glass, plate A glass that uses synthetic soda ash, which is made up of limestone and salt. See **limestone.**

glass roving See **roving.**

glass-rubber transition See **glass transition temperature.**

glass, safety See **safety glass.**

glass, silica See **silica.**

glass sphere micro- See **microsphere.**

glass sphere, solid Beads are used as fillers and reinforcements. They are available in a wide range of dimensions (5 to 1,000 μm). Their smooth shapes reduce abrasive and viscosity effects.

glass, switchable See **plastic, light-switchable.**

glass, tempered Glass with surface compressive stresses that are induced by heat treatment, resulting in toughened glass. See **safety glass.**

glass transition The reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from a viscous or rubbery condition to, or from, a hard and relatively brittle one that is usually brought about by changing the temperature. Also called *gamma transition* or *glassy transition.* See **crystalline plastic; designing with plastic-chemical models.**

glass transition temperature (T_g) The reversible change in phase of a plastic from a viscous or rubbery state to a brittle glassy state. T_g is the point below which plastic behaves like glass but remains very strong and rigid. Above this temperature it is not as strong or rigid as glass, but neither is it brittle. At T_g the plastic's volume or length increases, and above it, properties decrease. The amorphous thermoplastics have a more definite T_g when compared to crystalline plastics. It is usually reported as a single value. However, it occurs over a temperature range and is kinetic in nature. Example of the T_g range has PE at −125°C and PMMA at +105°C. Also called *glass-rubber transition.* See **orientation and glassy state; processing via fluorescence spectroscopy; thermomechanical analysis.**

glass transition temperature and brittleness The brittleness temperature of plastics can be related to T_g. Generally, thermoplastics below T_g are brittle; thermoset plastics are not brittle.

glass transition temperature and crystalline melting point Mechanical and physical properties are strongly dependent on temperature. A dramatic shift in properties is observed for linear amorphous plastics at the glass transition temperature. At or above the crystalline melt temperature (T_m), plastic molecular chains exhibit extensive transitional movement or flow.

glass transition temperature and melting temperature The Bower-Beaman rule is a statement of the relationship between T_g and melting temperature (T_m) of a plastic. The ratio of T_g/T_m (with Ts expressed in °K) usually lies between 0.5 and 0.7.

glassy state In amorphous plastics, below the T_g, cooperative molecular chain motions are frozen so that only limited local motions are possible. Material behaves mainly elastically since stress causes only limited bond angle deformations and stretching. Thus, it is hard, rigid, and often brittle. See **orientation and glassy state; stress; vitreous.**

glazing **1.** A transparent or translucent material. **2.** A smooth glossy surface. See **acrylglass plastic; acrylic plastic.**

globule A defect that is caused by the incomplete plastication of a piece of material during processing. The defect appears as a globule in an otherwise blended mass. See **defect; fish-eye.**

gloss **1.** The shine or luster of the surface of a plastic. **2.** See **coefficient of scatter; extruder roll cooling; film decorating; texturizing.**

gloss, non- See **iridescence.**

gloss, specular The relative reflective appearance of a material as determined visually. See **luminous fractional reflectance.**

glue An impure form of gelatin that is obtained by the action of heat and water on animal tissue such as bones and hides. Today there are many types, including fish, vegetable, casein, and plastic glues. Generally, glues absorb cold water and dissolve in hot water.

gluing See **adhesive.**

gluten See **adhesive gluten.**

glycerol ester A product of the esterification of glycerol with acids. It is used as a plasticizer in the production of certain compounds. See **plasticizer.**

glycol See **ethylene dichloride.**

goal, business See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

godet See **extruder godet unit.**

gold An element that is chemically nonreactive when attacked by chlorine and cyanide solutions in the presence of oxygen. It is used in plating mold cavities when processing with certain plastics or to obtain surface finishes on processed plastics. Note that a single ounce of gold, the most malleable of all metals, can be beaten out into a leaf or sheet measuring 300 ft^2 (27.9 m^2). Gold leaf can be as thin as four-millionth of an inch. See **mold-cavity coating.**

gold-leaf stamping See **stamping, hot.**

golf course, recycled See **landfill, recycled.**

goniometer An instrument that measures the angle through which a specimen is rotated.

good-manufacturing practice See **quality-system regulation.**

goods The manufactured/fabricated products that are complete and ready for shipment to the customer. Also called *finished goods* or *finished products.* See **energy efficiency.**

Goodyear, Charles See **rubber, natural.**

Gossamer Albatross aircraft See **aircraft, Gossamer Albatross.**

Gough-Joule effect See **heat effect, Gough-Joule.**

government contract directory An annual directory that lists over 50,000 contracts organized by product category order, and that includes the name and address of each awarding agency, a description of material/product, quantity, contract number, and dollar amount. It is sold via Government Data Publications, 1155 Connecticut Ave. NW, Washington, DC 20077. See **test, laboratories, worldwide approval of.**

government publication See **Appendix E, Government Publications and Groups.**

grading The size distribution of fillers and reinforcements.

grafting A deposition technique that bonds plastics to a wide variety of other materials. The grafting of two dissimilar plastics often involves a third plastic whose function is to improve the compatibility of the two principal components. See **compatibilizer agent; copolymer, graft; polymer, graft; radiation-induced reaction.**

grain The unidirectional orientation of plastic molecules or fillers (reinforcing, etc.) particles that results in anisotropy of the material. See **directional property.**

graining A plastic surface that looks like wood graining and is produced using a process such as molding, extruder film/sheet line roller, roller coating, or hot stamping. See **mold cavity; photoetching tool.**

granite, plastic A material that provides a solid, durable, beautiful surface. One class is a mixture of thermoset polyester plastic with alumina trihydrate fillers for installations subjected to uninterrupted usage. Another has acrylic plastic with alumina trihydrate fillers that provide resiliency.

granular material The nonuniform appearance of potential processable materials that is due to retention of, or incomplete fusion of, particles of composition, either within the mass or on the surface. See **plastic material.**

granular powder Particles that have about equal dimensions without spherical shapes.

granulator A device that changes scrap, rejects, and waste plastics so that they can be recycled. Granulator knife blades and sizing screens are selected from various sources depending on factors such as the type of plastic used, product thickness, shape, toughness, and so on. With heat-sensitive plastics (or even others), the granulator cannot cause overheating during the cutting actions. Thick plastics may require a series of different granulators so that incremental reduction occurs, eliminating overheating. For example, improper film granulators can encounter problems such as rotor wrapping, screen blinding, or bearing contamination. See **comminute; communition; pelletizing; recycling, cryogenic.**

granulator knife Maintaining granulater knives minimizes downtime. Knives are made of various materials (carbon base steels, alloy steels, tool steels, etc.) that meet the different requirements (wear, hardness, toughness, cost, etc.) of the plastic to be ground. They have various cutting edges (keen edge, reverse bevel, high or low shear, radial rotor, hook fly, etc.).

granule A small ceramic or natural-colored mineral pellet or grain that is used as a filler.

graphical database A data file that pictorially represents the material in the file, such as chemical structure, compound mix, product design, and production-line setup. See **EnPlot software; fishbone diagram.**

graphic art Plastics play various roles in the graphic arts, such as in artistic expression and in printing. Techniques of the graphic arts are also applied to plastics for functional or aesthetic purposes. See **art and science; artwork; computer-aided; computer graphic; computer plotter; printing, photoengraving; printing, photography and photomechanical; productivity.**

graphic character An alphabetical, numerical, or special graphic symbol. See **drawing centerline; optical character recognition.**

graphic character alignment The vertical or horizontal position of characters with respect to a given reference line.

graphic, molecular See **computer-aided molecular graphic.**

graphite A relatively soft, black material that is naturally occurring and made synthetically principally to produce graphite reinforcing fibers for plastics. It is a crystalline allotropic form of carbon used as a lubricating filler, additive, and reinforcing fiber. See **allotropy; fiber, graphite; fiber, graphite and carbon characteristic; mesophase.**

graphitization The formation of graphitelike material from organic compounds. The process of pyrolyzation occurs in an inert atmosphere at temperatures in excess of 2,000°C (3,630°F), usually as high as 2,480°C (4,500°F), and sometimes as high as 9,750°C (5,400°F), converting carbon to its crystalline allotropic form. Temperature depends on precursor and final properties desired. The carbon fibers develop a higher modulus of elasticity, and the product is usually identified as graphite fiber. During pyrolysis, molecules containing oxygen, hydrogen, and nitrogen are driven from the precursor fibers, leaving continuous chains of carbon. See **allotropy; fiber, carbon; fiber, graphite; isocyanate allophanate; mesophase; pitch; polyacrylonitrile plastic; precursor; pyrolysis.**

grass clipping See **landfill and degradation.**

grass, synthetic In 1965 the Houston-Texas astrodome's grass field died, and the following year 11,600 m^2 of synthetic grass was installed made from nylon 6.6 extruded fibers containing additives such as pigments and ultraviolet inhibitors. This fabric was secured by over 3 miles of zippers that used continuous operating injection molding machines. See **Astroturf; nylon plastic; zipper.**

gravimetric feeder See **material feeding and blending gravimetric.**

gravity The gravitational attraction of the mass or subject on earth. See **load; mass.**

gravity, absolute The density or specific gravity of a fluid at standard conditions. For example, with gases, absolute gravity is at 760 mm Hg pressure and 0°C temperature. Also called *absolute density.*

gravity acceleration The gravitational pull or acceleration that is due to gravity—32.16 ft/s/s (9.8 m/s/s). See **atmosphere; centrifuge, ultra-.**

gravity, center of A fixed point in a material body through which the resultant force of gravitational attraction acts.

gray goods/fabric See **fabric, gray.**

grease burnishing See **burnishing, grease.**

Greenbuilding Council See **vinyl composition tile.**

green dot A symbol on a package that means that solid-waste can be recycled.

green strength, material See **plastic green strength; tensile green strength.**

greige goods See **fabric, greige.**

grex See **yarn grex.**

Griffith theory See **design-failure theory, Griffith.**

grinding The removal of material usually by means of rotating rigid wheels containing abrasives. See **abrasive; comminute; machining; material, powder; photo-etching tool; sanding.**

grinding, attrition mill See **mill, attrition.**

grinding, ball mill See **mill, ball.**

grinding, centerless Grinding plastic components to required dimensions between abrasive wheels revolving at different speeds. See **machining.**

grit blasting See **mold-cavity grit blasting.**

grocery bag See **packaging, grocery-bag.**

gross domestic product (GDP) A country's economic growth or loss. It is the total value of goods and services produced in a country during a specific time period, usually one year. In the past GDP in the United States was growing at about 2.5 to 3.5%. More recently it has been lower, but now at an expected 3+%. In the past the plastics industry's manufactured goods were 2 to 3 times GDP, but growth dropped significantly and now it is expected to be higher, with processed plastics and materials estimated above $185 billion per year. Machinery sales have followed a similar up-down-up cycle, with sales estimated above $3 billion/year. See **plastic consumption; plastic-industry machine sales; plastic industry size; world trade.**

gross national product (GNP) A country's economic growth or loss. GNP was used in the United States until 1993 but was replaced by GDP (gross domestic product), which is used by the rest of the world. See **gross domestic product; plastic consumption; plastic industry size.**

grout See **plastic grout.**

growth, plastic See **plastic growth.**

guide See **design guide; die, film and sheet thickness for a.**

guillotine See **cutter, guillotine.**

gum An amorphous substance or mixture that, at ordinary temperatures, is either a very viscous liquid or a solid that softens gradually on heating. It either swells in water or is soluble in it. Natural gums, obtained from the cell walls of plants, are carbohydrates or carbohydrate derivatives of intermediate molecular weight. See **organic.**

gum, chewing See **chicle.**

gum compound A rubber or elastomer compound containing only those ingredients that are necessary for curing, such as vulcanization and small amounts of other ingredients for processing and coloring.

gunk molding compound See **compound, premix.**

gusset See **bag gusset.**

gutta-percha A rubberlike material obtained from the leaves and bark of certain tropical trees.

gypsum A natural hydrated calcium sulfate used in the production of plaster of Paris. See **plaster of Paris.**

H

habit See **crystallization habit.**
Hagen-Poiseuille law See **viscosity, Hagen-Poiseuille law of.**
hairline crack See **crack; crack, hairline; reinforced-plastic hairline craze.**
half-life See **chemical reaction, half-life.**
halftone photography See **printing, photography and photomechanical.**
halocarbon plastic A plastic that is based on material made by the polymerization of monomers composed only of carbon and halogen.
halogen A group of elements that are headed by fluorine in the vertical position of the periodic table—namely fluorine, chlorine, bromine, and iodine. The word means "salt forming." See **fluorine.**
halogenation Incorporating one of four halogen elements, usually chlorine or bromine, into a chemical compound. See **foam and blowing agent; phosphorous-base flame retardant.**
halogen heater See **thermoforming heater, halogen.**
hammer mill See **mill, hammer.**
hand lay-up See **molding, open-mold; reinforced-plastic hand lay-up.**
handle, bottle See **blow-molding handle.**
hard disk See **compact disc.**
hardener **1.** A substance or mixture that promotes or controls the curing reaction of a plastic or adhesive by taking part in the reaction, unlike a catalyst. **2.** A substance that is added to plastics or adhesives to control the degree of hardness of a film. See **accelerator; adhesive, cold-setting.** **3.** See **safety hardener.**
hardening, case A heat-treating process that imparts a hard surface to a material, such as certain steels and plastics, while their interior remains relatively soft and tough. The surface hardens to a relative shallow depth. See **annealing; temper.**
hardening, strain See **strain hardening.**
hardening, work An increase in resistance to further deformation with continuing distortion. Hardening and strengthening can be caused by the strain energy absorbed from prior deformation or the more popular via heating. See **hardening, case.**
hardness The resistance to indentation as measured under specific conditions such as depth of indentation, load applied, and time period. See **chemical and physical characteristics; cross-linking network characteristic; test, Barcol hardness; test, Brinell hardness; test, Knoop hardness; test, Mohs hardness; test, Rockwell hardness; test, scleroscope hardness; test, Shore hardness; test, Vicat hardness; toughness and area under the curve.**
hardness, durometer An arbitrary numerical value that measures the resistance to indention of a blunt indenter point of the durometer. The higher the number, the greater the indention hardness. See **rigidsol.**
hardware **1.** Computer, electrical, electronic, mechanical, electromechanical, hydraulic, and other equipment and parts that are associated with such operations as handling or preparing materials, fabricating parts, and storage. See **computer hardware; computer software.** **2.** All types of tools that are used to maintain all types of equipment. See **tooling.**
hardware reliability See **control-system reliability; reliability.**
hard water See **water, hard.**
hardwood See **wood, hard-.**
hazard A material or substance that in normal use can be damaging to the health and well-being of a person. See **adulterant; barrel-venting safety; burn; cadmium; carbon monoxide; casting, solvent; dioxin; dust, industrial; foamed polyurethane; lead; packaging biological substances; phosgene; plasticator safety; plasticizer, nontoxic; polychlorofluorocarbon; radioactive decontamination; risk, acceptable; safety; styrene monomer emission; toxicity; volatile organic compound; waste, hazardous.**
haze The degree of cloudiness in a plastic. It can represent the percentage of transmitted light that, in passing through a plastic specimen, deviates from the incident beam via forward scattering more than 2.5 degrees on average. When a parallel beam of light impinges normally at 90° on a test specimen that is not highly transparent and clear, significant fraction of the transmitted light is deviated in directions between 0° and 90° to the normal. This is often called *forward diffusion*; the term *scattering* tends to be reserved for polarized light. See **light transmission; polarized light.**
heat The form of energy that is associated with and proportional to molecular motion. Radiation, conduction, or convection can transfer it from one body to another. Sensible heat is accompanied by a change in temperature, but latent heat is not. See **ablative plastic; British thermal unit; calorie; energy consumption; testing and classification.**
heat absorbed See **entropy of transition.**
heat, adiabatic See **adiabatic.**
heat and photosensitive compound Thermochromic and photochromic compounds show changes in color

and in light absorption, transmission, or reflection depending on their time and temperature history.

heat bond See **label, heat-transfer.**

heat build-up A rise in temperature in a part that results from the dissipation of applied strain energy as heat or from applied mold cure heat. See **convection; hysteresis.**

heat capacity In a unit mass of material, the amount of energy that is required to raise the mass's temperature by one unit, such as 1°C. It can be measured either at constant pressure or constant volume. For amorphous plastics it increases with temperature in an approximately linear fashion below and above its T_g, but steplike change occurs near T_g. No such step change occurs with crystalline plastics. Also called *specific heat.* See **thermal analysis.**

heat-capacity change See **differential scanning calorimetry.**

heat, chemical reaction See **chemistry, thermo-.**

heat content, melt See **thermodynamic properties.**

heat control See **process control.**

heat deflection temperature (HDT) The most popular is deflection temperature under load. Also called HDTUL. See **deflection temperature under load versus crystallinity; test.**

heat degradation See **degradation.**

heat, dielectric A method of heating plastics by dielectric loss in a high-frequency electrostatic field. The material is exposed between electrodes. Heating is very quick and uniform due to the absorption of energy. The plastic to be heated forms the dielectric of a condenser to which is applied high-frequency (20 to 80 mc) voltage. Process is used for sealing or welding films, preheating thermoset molding compounds, and so on.

heat distortion point See **test, distortion-point heat.**

heated-tool welding See **welding, hot-tool.**

heat effect, Gough-Joule When an elastomer or rubber is stretched adiabatically (without heat entering or leaving the system), heat is evolved. This effect was first reported discovered by Gough in 1805 and rediscovered by Joule in 1859. See **adiabatic; elastomer; rubber; test, Wiegand pendulum heat.**

heat, electromagnetic energy See **welding, electromagnetic-induction.**

heat, emissivity See **emissivity.**

heat energy See **damping capacity.**

heat energy, calorie/material See **energy efficiency.**

heat endurance The time of heat aging that a material can withstand before failing to a specific physical test.

heat enthalpy See **enthalpy.**

heater A device that provides radiation, conduction, or convection heat. Heaters may be catalytic gas, electrical resistance, infrared, gas-fired, hot water or oil, and steam. See **convection; thermoforming heater.**

heater band An electrical resistance or induction heater (ceramic, mica, etc.) in the form of a cuff that encircles the barrel and provides the necessary heat. Common with extruder barrels are cast aluminum heaters and coolers or calrod elements in grooved aluminum elements. See **barrel heater; injection-molding machine barrel heater.**

heater, cartridge An electric resistance heater that is in the form of a circular rod.

heater zone See **barrel heater zone.**

heat exchanger A vessel or unit in which an outgoing liquor or vapor transfers a large part of its heat to an incoming cool liquid. With vapors, its latent heat of condensation is utilized to heat the entering liquid. Shell and tube type are widely used in which the hot liquid or vapor is contained while the cool liquid passes through the tubes. Tubes are usually arranged in coils or bundles for maximum contact with heat source. See **thermodynamic properties.**

heat, exotherm See **exotherm.**

heat, fatigue See **fatigue hysteretic heating.**

heat flow, rate of See **thermal transference.**

heat flux Energy incident on a surface element per unit time.

heat forming See **thermoforming.**

heat, frictional See **welding, friction.**

heat history See **residence time.**

heating and cooling See **pipe, geothermal.**

heating and weight change See **differential gravimetric analysis.**

heating, catalytic A device that produces heat without a flame and thus has little fire risk. To save energy, gas-fired catalytic heaters are replacing conventional electric and gas-fired heaters such as those used for thermoforming. They also provide some unique processing benefits, such as being more efficient than radiant electric-sheath or ceramic types and having a cooler radiant surface, which results in thermoforming sheets that reach forming temperature about 30% faster and with less risk of overheating. See **thermoforming heater, catalytic-gas.**

heating, dielectric In electronic heating, the plastic to be heated forms the dielectric of a condenser to which is applied a high-frequency (20 to 80 mc) voltage. Heating of materials occurs by the dielectric loss in a high-frequency electrostatic field. Heating is quick and uniform due to the absorption of energy. It is used in sealing and welding films. Also called *electronic heating.* See **curing, dielectric; dielectric; electrical conductivity; transfer molding.**

heating, induction A method of heating electrically conductive materials. Plastics are generally poor conductors and cannot be heated directly by this method; the process is used indirectly by including a metallic (conductive) material that transfers its heat to the plastics. See **welding, induction.**

heating, microwave Using ovens in the rapid heating of dielectric plastics, such as applicable molding powders, nylon overlap curing, vacuum-bag curing, and autoclave curing. Microwave heating is closely related to dielectric heating, with the main difference between the two being the higher (2 to 3 times) frequency. See **electromagnetic spectrum.**

heating, pre- The process of heating a material, prior to processing, to make it more workable or to reduce the processing cycle. Different methods of heating are used, such as hot-dry air, dielectric heat, and radio-frequency heat. See **heating, dielectric; extruder roll preheater.**

heating, self- A rise in temperature of a plastic or product caused by internal, exothermic chemical reaction. See **exotherm.**

heating, shear See **shear heating.**

heating, viscous Heating that is generated within the stock (melt) by the friction that occurs during the mechanical working of the plasticator screw rotating in a barrel.

heat insulation R-value See **insulation R-value, heat.**

heat, latent The quantity of energy in calories per gram that is absorbed or given off as a substance undergoes, with no temperature change, a change from liquid to solid (freezes), from solid to liquid (melts), or from vapor to liquid (condenses). See **boiling point.**

heat mark See **sink mark.**

heat of activation The increase in enthalpy that occurs when a substance is transformed from a less active to a more active form at constant pressure.

heat of adsorption See **adsorption, heat of.**

heat of combustion The amount of heat that is released in the oxidation of a substance at constant pressure or constant volume. Also called *heat value* or *heating value.*

heat of fusion See **molar heat of fusion.**

heat of hydration See **hydration.**

heat of solution The heat that is evolved or absorbed when a certain amount of solute, a dissolved substance, is dissolved in a specific amount of solvent. See **solute.**

heat pipe A heat-transfer device that either removes or adds heat in all kinds of fabricating equipment. Compared to metals, pipes have an extremely high heat-transfer rate. They are capable of transmitting thermal energy at near sonic isothermal conditions and at near sonic velocity. They are tubular structures that are closed at both ends and that contain a working fluid. For heat to be transferred from one end of the structure to the other, the working liquid is vaporized. The condensed vapors travel to the opposite end, where the condensate becomes a working liquid again and returns to the original end of the pipe. Also called *thermal pins, heat transfer devices,* or *heat conductors.* See **heat sink; mold core.**

heat profile The heat that is required by the process material. For example, amorphous material usually requires a fairly low initial heat in the screw plasticator to preheat material but not melt it in the screw's feed section prior to entering the compression zone. Crystalline material requires higher initial heating to ensure that it melts prior to reaching the compression zone. See **product size.**

heat proportioning See **temperature proportional-integral-derivative.**

heat protection See **ablative plastic; coating, intumescent; flame retardant.**

heat resistance See **coating, intumescent; insulation resistance; pigment, metal chelate; pyrrone plastic; temperature properties of plastics; thermal data.**

heat reversible See **coefficient, Peltier.**

heat sealing See **coextrusion; sealing, heat; welding; welding, radio-frequency.**

heat sensitizer A gelling agent that is effective only at elevated temperatures.

heat shield See **ablative plastic.**

heat shrinkable tubing See **orientation and heat-shrinkability; tubing, heat-shrinkable.**

heat sink A device that absorbs or transfers heat away from a critical element or part. Bulk graphite is often used as a heat sink. See **heat pipe.**

heat softening point See **test, Vicat hardness.**

heat, specific See **heat capacity.**

heat stability The resistance of plastic to instability when subjected to heat during processing or in service. See **pigment.**

heat stabilizer An additive that improves the heat stability of plastics so that changes do not occur to its properties. See **barium stearate.**

heat staging See **plastic heat staging.**

heat sterilization See **sterilization, heat.**

heat test See **test, Wiegand pendulum heat.**

heat transfer The transmission of thermal energy by means of a temperature gradient that exists between two locations by conduction, convection, or radiation. See **devolatilization; printing, roll-on; thermal data; thermal diffusivity.**

heat-transfer fluid (HTF) A substance that is used in different processes to control mold, die, barrel, screw, and platen temperatures. It provides high temperatures at low system pressures, offering safety, low maintenance, and extended operating lifetime benefits. As a comparison, the pressure of 600°F steam is more than 1,500 psi. At the same temperature HTF has vapor pressure less than 1/3 atm pressure. Also called *hot oil* or *thermal fluids.*

heat-transfer, label See **label, heat-transfer.**

heat-transfer mechanism The barrel and screw combination is a complex heat-transfer system. To understand something that seems as simple as a zone override can require a complete analysis of the system. The factors that can cause a zone override include screw design, barrel mass, thermocouple placement, cooling jacket fit, barrel and screw wear, head pressure, overall temperature profile, defective temperature controllers, and inadequate cooling. Before assuming that zone override is strictly a screw-design problem, you should analyze the system as a complete heat-transfer mechanism. Although the screw is responsible for most of the heat transfer, it cannot control the heat distribution. See **barrel; extruder; injection molding; melt temperature; screw.**

heat-transfer printing See **printing, heat-transfer.**

heat treating See **annealing; hardening, case.**

heavy metal See **metal, heavy.**

hemocompatibility The state of being inert or minimally interactive with the environment and living organisms. Blood represents one of the most complex biochemical systems in living organisms and has multiple functions. Because these functions are critical, medical devices that contact blood must be hemocompatible and must not adversely interact with any blood component. See **chemistry, bio-compatibility; ISO-10993 certification.**
hemp A soft, white fiber that is obtained from the stems of the plant *Cannabis satira.* It is used as a filler and plastic reinforcement. See **filler; reinforcement.**
hermetic seal See **seal.**
Hertz (Hz) A unit of frequency that is equal to one cycle per second.
heterocyclic compound A compound that contains molecules whose atoms are arranged in a ring; the ring containing two or more elements.
heterogeneous See **equilibrium, heterogeneous; mixture, heterogeneous; nucleation, heterogeneous; plastic material, heterogeneous.**
high-density polyethylene See **polyethylene plastic, high-density.**
high polymer See **polymer, high.**
hinge, integral See **design hinge, integral.**
Hinterspritzen bag molding See **reinforced-plastic-bag molding.**
history See **people and machines; plastic history; polymerization history; recycling; Staudinger, Hermann; testing and classification.**
hobbing See **mold-cavity hobbing.**
hold time **1.** In welding, the length of time allotted for the melted plastic to solidify. See **welding. 2.** In process engineering, the residence time of an individual ingredient in a reaction vessel or other processing apparatus. Also called *holding time.*
hole, blind A hole that is not molded entirely through a part. See **broach.**
holography The production of a unique three-dimensional image on photographic plastic film by means of an interference pattern created by a laser beam that is split by a mirrorlike device. It was developed in 1947 by Dennis Gabor of the Imperial College of Science and Technology, London, UK, while working on improving an electron microscope. See **computer acoustic holography; cross-linking, radiation; light, white; test, nondestructive acoustic holography.**
homogeneity See **mixture, homogeneity.**
homopolymer See **polymer, homo-.**
honeycomb core See **core, honeycomb or foam.**
honing See **mold-cavity honing.**
Hook's law See **modulus of elasticity.**
hoop stress See **stress, hoop.**
hopper A receptacle on the fabricating machine (extruder, injection molding, blow molding, etc.) that directs the plastic materials (pellets, granules, flakes, etc.) that are fed into the plasticator. Measuring plastic usage for a given process helps determine how much plastic should be loaded into the hopper. The hopper should hold enough plastic for possibly one-half to 1 hour's production to prevent storage in the hopper for any length of time. Care should be taken to ensure that hygroscopic plastics are in an unheated hopper for no more than one-half to 1 hour or as determined from experience or specified by the material supplier. See **barrel; magnet.**
hopper blender See **blender.**
hopper, color Hopper-mounted coloring loaders combine virgin plastics, regrinds, one or more colorants, or additives (such as slip agents, inhibitors, etc.). Materials are mixed by tumbling or gravity and drop the mixture into the process hopper. Some coloring loaders allow use of dry, powdered colorants, color concentrates, or liquid colorants through the same unit without major equipment alterations. They are self-loading and mount directly over processing machines so there is no need to manually handle component materials and risk contamination and waste. When powdered dry colorants are used, they can be placed in a canister in a separate color room, and the filled canister is then mounted on the coloring loader. See **colorant.**
hopper disc feeder A horizontal, flat, grooved disc that is installed at the bottom of a hopper that feeds a plasticator and that controls the feed rate by varying the disc's speed of rotation or varying the clearance between discs. A scraper is used to remove plastic material from the discs. See **mixer.**
hopper dryer A combination feeding and drying device where hot air flows upward through the hopper containing the plastics to be processed. See **drying operation.**
hopper feeder A device that feeds plastic to the hopper. Hoppers may be manual or sophisticated automatic material-handling systems. Vacuum or positive air-pressure systems are used. The type used depends on factors such as available space, type of plastic (shape, form), blending or mixing requirements, amount to be processed, and delivery rate. See **feed hopper.**
hopper magnet See **metal detection.**
hopper stuffer A device that is used to handle paste-type molding compounds that do not flow through conventional hoppers. It moves material into the plasticator. It usually includes a ram or a screw, with the screw also acting as a plunger, and may include a preheater for the material.
hopper, vacuum The vacuum that is used to remove volatiles.
hot working See **shaping mechanically.**
house See **plastic house; pipe, geothermal.**
hue A particular color; a quality that distinguishes colors in the visible portion of the spectrum. The first of three dimensions of color are hue, lightness, and saturation. See **colorant; light; saturation.**
humectant agent, moisture See **moisture, humectant agent.**
humidify To increase, by any process, the quantity of water vapor within a given space.

humidity The condition of the atmosphere in respect to water vapor.
humidity, absolute The weight of water vapor that is present in a unit volume of air—for example, g/cm^3.
humidity, atmospheric hygrometer An instrument that measures the humidity of the atmosphere.
humidity ratio In a mixture of water vapor and air, the mass of water vapor per unit mass of dry air.
humidity, relative See **relative humidity.**
humidity, specific In a mixture of water and air, the mass of water vapor per unit mass of moist air.
Hyatt, John Wesley (1837–1920) During the 1860s John Wesley Hyatt developed cellulose nitrate plastic and successfully produced and marketed billiard balls as a less expensive alternative to ivory billiard balls. See **cellulose nitrate plastic; plastic history.**
hybrid **1.** A combination of two or more machines or equipment. For example, machines that use hybrid clamping pressure systems combine different power systems (straight hydraulic ram with toggle unit, hydraulic units with electrical devices, etc.) **2.** Many different hybrids exist that use two or more different materials that are processed together (coextrusion, coinjection, laminate, reinforced plastic constructions, etc.). **3.** Hybrid combinations provide synergistic gains, including cost reductions. See **composite; reinforced plastic.**
hybrid interplay A laminate in which more that one material is used within a specific layer.
hybrid motion control See **motion-control system type.**
hydrate See **water of hydration.**
hydration Causing, taking up, or combining with water or the elements of water, resulting in a hydrate. See **water of hydration.** Heat of hydration is the energy released as heat during the chemical (hydration) reaction, such as curing a thermoset plastic reaction, when water solidifies Portland cement, and recycling of plastics. See **recycling, chemical.**
hydration, de- See **barium oxide.**
hydraulic Pertaining to an operation in which a liquid is used to exert or transfer pressure. See **clamping, hydraulic; injection-molding screw drive; pneumatic.**
hydraulic actuator See **motion-control system.**
hydraulic damping action See **damping, dash pot.**
hydraulic fluid influenced by heat Excessive heat in the operation of machine hydraulic systems (injection molding, etc.) can have negative effects on the machine operation if not properly controlled. Excessive heat depletes the oxidation inhibitors of fluid oil, causing fluid to be contaminated (sludge, etc.). See **injection-molding machine, hydraulic operation of.**
hydrocarbon One of a large group of chemical compounds that is made of carbon and hydrogen. Its largest source is petroleum crude oil. See **oil and gas; oil, crude.**
hydrocarbon, plastic See **plastic hydrocarbon.**
hydrocarbon solvent See **solvent, hydrocarbon.**
hydrochloric acid (HCl) A solution of hydrogen chloride gas in water. It is a poisonous, pungent liquid that forms a constant boiling mixture at 20% concentration in water. It is widely used as a chemical reagent in organic synthesis, food processing, metal cleaning, and so on. Also called *muriatic acid.* See **chemical reagent; hydrogen chloride; recycling steel with vinyl scrap; zirconium.**
hydrochlorofluorocarbon (HCFC) A substance that contains less chlorine than polychlorofluorocarbons (PCFCs). It has been used as an interim blowing agent for polyurethane foams. See **polychlorofluorocarbon.**
hydroclave See **autoclave molding operation.**
hydrodynamics A branch of science that deals with the motion of fluids and the forces that act on solid bodies that are immersed in fluids and in motion relative to them. See **cavitation; pressure; hydrostatic.**
hydrogel A colloid in which the dispersed phase (colloid) has combined with the continuous phase (water) to produce a viscous jellylike product. During the past quarter century, synthetic hydrogel technology has developed from a theoretical concept into a multimillion-dollar segment of the biomedical and specialty plastic industry. See **lens, contact.**
hydrogen (H) The first chemical element in the periodic table. It is the lightest element, with an atomic weight of about one. H_2 is a highly flammable, colorless, tasteless gas and is slightly soluble in water. It is used in the production of synthetic ammonia, in the hydrogenation of many organic materials, and as a reducing agent for organic synthesis.
hydrogenation The introduction of hydrogen into plastics using a variety of catalysts and a wide range of conditions. Destructive hydrogenation of natural and synthetic polymers at high temperatures has been helpful in determining the structures of polymers. An important benefit resulting from hydrogenation is increased stability. For example, polybutylene, of which 90% of the original double bonds have been saturated, shows good resistance to ozone. See **chemical dehydrogenation.** The process is used in recycling plastics in a hydrogen atmosphere at 300 to 500°C (572 to 932°F) and 100 to 400 bar pressure to produce a mix of 65 to 90% oil or synthetic crude, 10 to 20% gases, and up to 20% solid residues. See **recycling, chemical; recycling method, economic evaluation of.**
hydrogen atom bonding A special type of intermolecular attraction that occurs between a hydrogen atom that is bonded to an atom of a very electronegative element (F, N, or O) and another atom of one of these three elements.
hydrogen chloride (HCl) A fuming, highly toxic, colorless gas that is soluble in water, alcohol, and ether. It is used in the production of PVC and alkyl chloride and in polymerization, isomerization, and other reactions. See **electrical insulation, askarel; hydrochloric acid.**
hydrogen, de- See **chemical dehydrogenation.**
hydrogen embrittlement Hydrogen-induced cracking or severe loss of ductility that is caused by the presence

of hydrogen in materials, particularly metals. See **brittleness; embrittlement; extruder film brittleness; toughness; viscoelasticity.**

hydrogen peroxide See **sterilization, vapor-phase hydrogen peroxide.**

hydrological cycle The cycle of water—from bodies of water (oceans, etc.), through evaporation, to water-vapor condensation as clouds, and eventual release back to the earth as some form of precipitation (rain, etc.). If water is contaminated, it can be filtered through the earth prior to its way back to a body of water. See **water.**

hydrolysis The chemical decomposition of a material that involves the addition of or reaction with water. See **chemical reclamation; drying operation, hygroscopic plastic; injection-molding venting; plastic, hygroscopic; waste; water.**

hydrolytic stability The ability of a material to withstand the environmental effects of high humidity. See **hygroscopic; recycling, chemical.**

hydrophilic A substance that interacts favorably with polar water molecules. It means "water-liking." It has an affinity for water, is wettable by water, and tends to absorb water, as opposed to lyophobic. See **lyophilic; oleophilic; water.**

hydrophilic surface A surface of a hydrophilic substance that has a strong ability to bind or absorb water; a surface that is readily wettable with water. An example is a carbohydrate such as starch. See **emulsifying agent; fiberglass binder/sizing coupling agent; ion-beam surface modification.**

hydrophobic Capable of repelling water, lacking affinity for water. See **antifogging agent; emulsifying agent; water.**

hydrosol A suspension of PVC or nylon plastic in water. See **latex.**

hydroxyl group See **atom, hydroxyl group.**

hydrostatic A branch of physics that deals with the characteristics of liquids at rest and with the pressure in a liquid or exerted by a liquid on an immersed body. See **hydrodynamics; pressure, hydrostatic.**

hydrotropy The increase in solubility of a substance that is only slightly soluble in an aqueous system by the addition of a third substance. This third substance is called a *hydrotropic agent.*

hydrous Indicating the presence of an indefinite amount of water.

hydroxy See **chemical, hydroxy group.**

hydroxy group See **atom, hydroxyl group.**

hygrometer **1.** An instrument that measures the surface temperature at which ambient water vapor condenses. **2.** An instrument that determines the relative humidity of the atmosphere. See **relative humidity. 3.** An instrument that measures the water-vapor content of hygroscopic and other plastics by measuring the change in resistance or capacitance. See **drying operation, hygroscopic plastic.**

hygrometer, humidity atmospheric See **humidity, atmospheric hygrometer.**

hygroscopic Tending to absorb moisture; capable of adsorbing and retaining atmospheric moisture. See **drying; drying operation, hygroscopic plastic; injection-molding venting.**

hygroscopic, plastic See **drying operation, hygroscopic plastic; plastic, hygroscopic.**

hydrothermal effect A change in properties due to moisture absorption and temperature changes. See **water.**

Hypalon DuPont's trade name for its chlorosulfonated polyethylene elastomers.

hypodermic needle See **blow molding, extruder blow-action.**

hypothesis A supposition or conjecture that is put forward to account for certain facts and is used as a basis for further investigation by which it may be proved or disproved. Also called *blind search.* See **debug; design-failure theory; problems and solutions; troubleshooting.**

hysteresis The incomplete recovery of strain in a material that is subjected to a stress during its unloading cycle due to energy consumption. This energy is converted from mechanical to frictional energy (heat). It can represent the difference in a measurement signal for a given process property value when approached first from a zero load and then from a full scale. See **accuracy; fatigue hysteretic heating; repeatability; strain; stress.**

hysteresis control See **control, transducer-specification.**

hysteresis diagram In fatigue, the stress-strain path during a cycle. See **fatigue S-N diagram.**

hysteresis, elastic The difference between the resilience of a material at a specific stress and deformation energy that is recovered from the material unloaded from the same stress, the loading and unloading occurring at a constant and specified rate. See **damping.**

hysteresis heat build-up The accumulation of thermal energy generated within a material as a result of hysteresis, evident by an increase in temperature. See **fatigue hysteretic heating.**

hysteresis loop In dynamic mechanical measurement, the closed curve representing the successive stress-strain status of the material during a cycle deformation. See **damping, mechanical; energy deformation; tensile hysteresis.**

hysteresis loss The loss of mechanical energy due to hysteresis.

hysteresis measurement Dynamic testing, determines the number of cycles to break and establishes causes and patterns of failure. Stress and strain (extension) are measured, and the elastic modulus is derived from these values. This assists in a complete description of the failure pattern. See **dynamic mechanical measurement; stress-strain curve.**

hysteresis, mechanical The energy that is absorbed in a complete cycle of loading and unloading, including any stress cycle regardless of the mean stress or range of stress.

hysteretic heating See **fatigue hysteretic heating.**

I

ice, dry A solid form of carbon dioxide (CO_2) that is available in various forms, such as snow, blocks, and nuggets. When dry ice pellets are sprayed, they are usually at 200 to 250 psi (1.4 to 1.6 MPa). Dry ice is used to deflash, shrink fit, perform inert cooling, and so on. See **cleaning; deflashing, cryogenic.**
icephobic coating An anti-icing coating. See **polyphosphazene plastic.**
ice, synthetic Extruded plastic sheets, such as HDPE, that are used in ice skating rinks. The rink at Madison Square Garden, New York City, has used this "super ice" since 1985. It has 94% of the glide factor of wet ice; no use is made of the glide solution required on wet ice.
icing See **polyphosphazene plastic.**
ignition The initiation of combustion. See **combustion.**
ignition loss **1.** The difference in weight of a substance before and after burning. **2.** The burning off of a binder or sizing, as with glass fiber. See **fiberglass binder/sizing coupling agent; reinforced-plastic ignition loss; volatile.**
ignition point See **combustion, autoignition point; pyrophoric material.**
ignition temperature The lowest temperature at which sustained combustion can be initiated under specific testing conditions. See **test, fire cone and lift.**
ignorance factor See **factor of ignorance.**
image See **dye toner; optical density; optical distortion value; printing, electrostatic-charged area development; quality indicator, image.**
image, charge couple device (CCD) An electronic scanning device that is used in image systems.
image magnification See **transmission, electron-microscope.**
imide A nitrogen-containing acid that has two double bonds that are used to produce a family of temperature-resistant plastics, such as polyimide, polyetherimide, and polyimide-imide. See **polyamide-imide plastic; polyimide plastic.**
immiscible Not soluble; incapable of attaining homogeneity. The term also refers to powder and other solid materials that differ widely in some physical property, such as specific gravity. See **solubility.**
impact adhesive See **adhesive, contact.**
impact energy See **energy absorption; impact strength.**
impaction A forcible-impact contact. Also called *impingement.* See **test, aircraft canopy; test, impact.**
impact modifier A substance, usually a semicompatible rubber, that is added to a compound to improve impact resistance. Its particle size must be carefully controlled and have good adhesion or at least good wettability when dispersed in a compound. Too much compatibility would have it exhibit behavior similar to plasticizers. See **additive; plasticizer.**
impact resistance The resistance to fracture under shock force. See **safety glass.**
impact strength The tendency of a material to accept a sudden blow or shock without fracture or substantial damage. It is the energy required to break a specimen. It is equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact and the energy remaining after complete fracture of the specimen. Also called *impact energy.* See **automobile bumper fascia; energy absorption.**
impalpable powder See **material, powder.**
impingement mixing See **mixing, impingement.**
impregnation Saturating a material with plastic to provide increased performance or decoration. For example, application as a matrix reinforces fiber, producing exceptionally high-strength structures; saturating cement, concrete, wood improves strength and extends environmental endurance; filling metals that are slightly porous seals them. Degree of impregnation or saturation depends on variables such as process used (coating, extrusion, tower drying, etc. with or without vacuum in the substrate) and plastic melt capability. See **compregnate; embedding; extruder profile, coated; fabric, impregnated; metal impregnation; plastic-concrete composite; wood, compreg; wood-plastic impregnated.**
impregnation, fabric See **twist, direction of yarn.**
impregnation, introfaction A change in fluidity and wetting properties of an impregnated material that is produced by the addition of an introfier. See **chemical introfier; fluidity.**
impregnation overlay See **sheet overlay.**
impregnation, pre- Preparing a thermoplastic or thermoset plastic for impregnation, such as by drying or removing air or other gases (vacuum). With TS, partial B-stage plastic cure is usually performed. See **prepreg; reinforced-plastic preimpregnation; reinforced-plastic prepreg; sewer rehabilitation.**
impregnation, trickle A process that is related to thermoset plastic casting, potting, and encapsulation in that it also uses low viscosity liquid reactive plastics to provide the trickle impregnation. For example, the catalyzed plastic drips onto an electrical transformer coil. Capillary action draws the liquid into its openings at a rate slow enough to enable air to escape as it is displaced by the liquid. When fully impregnated, the part is exposed to heat to cure the plastic.
impregnator A device that impregnates, such as a

heated vacuum chamber for solid products or sheet material passed through a heated tunnel.

impulse sealing See **sealing, impulse.**

impurity See **material impurity; scavenger.**

inching See **compression-molding inching; mold inching.**

inch unit See **angstrom; micron unit.**

incineration Controlled burning of solid, liquid, or gas wastes to break them into gas byproducts and ash. Plastics are a safe component in modern municipal waste-incineration facilities, which are equipped with pollution-control devices. Because plastics are practically all petroleum or natural gas derivatives, they burn at a higher temperature than other wastes and help to make the combustion process more complete. Plastics can safely reduce waste volume by 90 to 98% and convert that waste to useful energy. See **ash; ash content; carbonaceous matter; combustion modular unit; dioxin; energy efficiency; flammability; hazard; plastic and pollution; plastic, long-life; recycling, chemical; scrubber; solid-waste volume reduction.**

incineration and energy When compared to other materials in municipal trash and waste, plastics produce much more energy. See **design-source reduction; energy consumption; energy reclamation; landfill and degradation; pollution; pyrolysis; recycling cost; recycling limitations; recycling method, economic evaluation of.**

incineration fume system One of four basic types of fume systems that use thermal oxidizers to destroy volatile organic compounds (VOC) by converting hydrocarbon-laden fumes to water vapor and carbon dioxide. Different scrubbers are used. While each system effectively eliminates VOCs, the systems have varying operating performances and costs. They have different oxidation theories identified as common afterburner, catalytic converter, recuperative thermal oxidizer, and regenerative thermal oxidation. See **energy reclamation; scrubber; volatile organic compound.**

index of refraction See **light index of refraction.**

indirect cost See **cost, direct and indirect.**

induction bonding See **insert induction bonding.**

induction, magnetic Flux density in a magnetic field.

industry input/output data See **standard industrial classification.**

industry recycling See **World of Plastics Reviews: Challenge 2000—Making Plastics a Preferred Material.**

industry show See **shows and conferences; Appendix C, Worldwide Plastics Industry Associations.**

industry size See **plastic industry size.**

industry worker certification See **processor certification.**

inelastic deformation See **deformation, inelastic.**

inert Not chemically reactive. See **additive, inert.**

inertia **1.** The property of matter whereby a body remains at rest or in uniform rectilinear motion unless acted on by an internal force. **2.** Sluggishness or slowness to take action. See **fabricating output; moment of inertia.**

infrared (IR) The part of the electromagnetic spectrum between the visible light range and the radar range. Radiant heat is in this range, and IR heaters are frequently used in the thermoforming process and the curing of thermoset plastics, including reinforced plastics. See **finish, baking; light, white; test, nondestructive temperature differential by infrared; wavelength.** IR analysis is used for identification of plastic constituents, quality control, and so on. See **electromagnetic spectrum; quality control, sensor, infrared; test, infrared; wavelength; welding, infrared.**

infrared (IR) annealing Raising the temperature of a plastic part to a target level by using IR. IR annealing provides an extra measure of safety in complex-shaped parts, where stress-cracking failures can be critical. The process can also be used to improve plating or coatings since IR annealed parts are more resistant to the cracking or crazing that is often associated with aggressive coatings. Fully assembled parts can be annealed, which can be beneficial where excess stress due to assembly is present. With oven annealing aging can be accelerated leading to embrittlement and loss of toughness, and longer heating times require more energy costs. See **annealing.**

infrared inspection See **inspection, infrared.**

infrared (IR) spectroscopy A method that is used to observe and plot the wavelengths in the electromagnetic spectrum that lie beyond the red from about 750 mm (730 A) to a few millimeters. See **absorption; chemistry, analytical; cross-linking, radiation; quality-control online infrared measurement; radiation; spectrometer, ultraviolet; spectroscopy, Fourier's transfer infrared; thermal analysis.**

infrastructure The underlying foundation or basic system framework. For example, plastics are involved in the highway infrastructure when reinforced plastics are wrapped around roadway and bridge concrete columns when they require retrofitting, such as after long use or an earthquake.

infringement See **legal matter: patent infringement.**

infusible Not capable of being melted, which is typical of thermoset plastics.

infusion The aqueous solution of a soluble constituent of a substance that is the result of the substance's steeping in a solvent for a period of time. See **solution.**

infusion molding See **reinforced-plastic resin transfer molding.**

ingot A large casting that subsequently goes into secondary operation, such as being rolled, forged, skived. See **film, skived.**

inherently dissipative plastic See **plastic, electrically conductive.**

inherent viscosity See **viscosity, inherent.**

inhibitor A material that is designed to slow down or prevent a chemical reaction; to be technically useful, it must be effective in low concentration. If the inhibition is for compounding purposes, then it can be called a *stabilizer.* See **catalyst, negative; retarder.** Inhibitors are also used in certain plastics to prolong storage life. See **shelf life.**

initiator The substance or molecule, other than a reactant, that initiates a chain reaction, as in polymerization or for cross-linking thermoset plastics. See **cross-linking; ionic initiator; polymerization.**

injected paint technology See **paint coating, in-mold.**

injection blow molding See **blow molding, injection.**

injection/blow molding with rotation See **blow-molding, injection-with-rotation.**

injection-compression molding (ICM) A variant of injection-molding thermoplastics. The essential difference lies in the manner in which the thermal contraction in the mold cavity that occurs during cooling (shrinkage) is compensated. With conventional injection molding, the reduction in material volume in the cavity due to thermal contraction is compensated basically by forcing in more melt during the pressure-holding phase. By contrast with ICM, a compression mold design is used where a male plug fits into a female cavity rather than the usual flat-surface parting-line mold halves for IM. The melt is injected into the cavity as a short shot, thereby not filling the cavity. The melt in the cavity is stress-free; it is literally poured into the cavity. Prior to receiving melt, the mold is slightly opened so that a closed cavity exists; the male and female parts are engaged so the cavity is closed. After the melt is injected, the mold automatically closes producing a relatively even melt flow. On controlled closing, a very uniform pressure is applied to the melt. Sufficient pressure is applied to provide a molded part without stresses. This type of molding has many advantages in favor of molded part performances. Also called *coining* and *injection stamping.* See **injection molding, controlled-density; injection molding, foamed high-pressure.**

injection molding (IM) A method for producing molded plastic. Worldwide, extrusion uses 36wt% of plastics, and IM uses 32wt% of all plastics. IM is basically a noncontinuous extruder and in some operations is a continuously operating machine. It has a screw plasticator (also called a *screw extruder*) that prepares the melt. The injection-molding machine can be identified by two popular methods of operation—the one-stage molding system and the two-stage molding system. There are also three-stage molding units. The one-stage is more popularly known as the reciprocating-screw IMM. The popularly known two-stage has other names such as the *piggy-back IMM* that can be related to a continuous extruder. See **extruder; blow molding, extruder (intermittent).**

Injection-molding machines (1) plasticize (heating and melting of the plastics), (2) inject (injecting under pressure a controlled volume shot of melt into a closed mold with solidification of the plastics beginning on the mold's cavity wall), (3) after-fill (maintaining the injected material under pressure for a specific time period to prevent back flow of melt and to compensate for the decrease in volume of melt during solidification), (4) cool (cooling the molded part in the mold until it is sufficiently rigid to be ejected), and (5) release the molded part (opening the mold, ejecting the part, and closing the mold so it is ready to start the next cycle with a shot of melt). See **World of Plastics Reviews: The Plastics Industry; World of Plastics Reviews: Basics and Overviews of Fabricating Processes.**

The IMM features three basic components—injection unit, mold, and clamping system. The injection unit prepares the proper melt and transfers the melt into the next component, which is the mold. The clamping unit closes and opens the mold. This operation tends to be more complex than other processes since it involves moving and stopping the melt flow into the mold, rather than having a continuous flow of melt without interruptions. The IM process is extremely useful since it permits the manufacture of simple to particularly very complex and intricate three-dimensional shapes. When required these shapes or parts can be molded to extremely tight tolerances, very thin, and relatively low weights in grams. See **injection-molding machine, reciprocating screw; injection-molding machine, two-stage; automation, vision.**

injection-molding accumulator See **accumulator.**

injection-molding aircraft canopy IM canopies are always made by thermoforming acrylic plastic, polycarbonate plastic, or their combinations. During the early 1980s successful IM canopies were fabricated, but for the rather limited production of canopies, thermoforming continues to be used. See **aircraft; canopy; transparent.**

injection-molding air shot The contents of a plasticator shot expelled into the air to study the characteristics of the melt; usually performed on start-up with the mold in the open position. Also called *air purge.* See **air entrapment.**

injection molding, automotive See **automobile, composite.**

injection molding, back-molding A technique that can replace the production of bonding decorative material parts to an IM exterior part. This exterior or cover laminate or decorative film or sheet is placed in the mold prior to injecting the plastic melt, usually at low pressure, using standard or slightly modified IMMs. Also called *in-mold* or *low pressure IM.* See **injection molding, in-mold; injection molding, two-shot.**

injection-molding back pressure See **back pressure.**

injection molding, blow See **blow molding, injection.**

injection molding, boost cut-off or two-stage control A basic process control that provides a method of controlling the IM process via the cavity pressure control to hold consistent injection fill time. The boost cutoff approach can be interpreted incorrectly due to its simplicity; some of the subtleties involved in its use are often overlooked. When molding with a machine that has no closed-loop control, the most generally accepted molding practice is to mold with enough pressure on the first-stage or high-volume pump to fill and pack the cavity. The first-stage pressure is initiated at the start of the injection cycle and is maintained by the first-stage timer. This timer is set with enough time available so that the mold cavity can be completely filled and packed before the timer has completed its cycle. When the timer completes its cycle, the machine control switches from a first-stage to a second-stage pressure. Second-stage pressure is set to a level sufficient to hold the material in the cavity until the plastic solidifies. This technique requires a cushion of plastic melt ahead of the screw. The cushion allows pressure in the injection cylinder to be transferred to the mold cavity so that the packing and holding portions of the cycle can occur.

Having provided the excess energy necessary to achieve cavity fill, coupled with the correct use of flow control to keep the fill rate constant, it is only necessary to know when to turn the energy off to ensure the proper degree of packing. The point where the energy is turned off is called the *boost cutoff* or *degree of packing cutoff* (DPC) set point. Mold pressure continues to rise after this set point is reached until a peak pressure is obtained. This continued rise in pressure is called the *overshoot* of the control system. If the screw or plunger is moving at a lower rate of speed when the cutoff is reached, there will be very little overshoot that is caused by the screw or plunger deceleration. The amount of overshoot is a variable that depends primarily on fill rate. To compensate for overshoot, the molder may have to fine tune the boost cutoff set point when fill rate changes are made in the process. See **mold-cavity pressure; process control.**

injection molding bridging See **screw and barrel bridging.**

injection molding, bulk-molding compound (BMC) Different IMM designs are used to process BMC, but use a stuffer feed-box system. See **hopper stuffer; reinforced-plastic bulk-molding compound.**

injection molding bumping See **mold breathing.**

injection-molding capacity See **injection-molding machine characteristic.**

injection-molding carousel See **clamping platen, rotary.**

injection molding, cavity fill and pack See **injection molding, boost cut-off or two-stage control.**

injection molding change-over time The period of time that elapses from when the molding is ready to be ejected or removed to the time when the operating cycle is about to be started again.

injection molding circuit board IM wire boards provide significant savings over laminated types. The three-dimensional features such as spacers, stand-offs, soldering sites, and holes for through-hole connections can be molded. See **printed circuit board.**

injection molding clamping See **clamping.**

injection molding cleaning See **cleaning.**

injection molding, co- See **coinjection molding; injection molding, sandwich.**

injection molding coaxial cable See **electrical cable "button."**

injection molding cold shot An incomplete part that is formed while cycling a machine during heat up or start up. See **extruder cold shot.**

injection molding cold slug See **molding cold slug.**

injection molding communication protocol See **communication protocol.**

injection molding, computer-integrated See **computer-integrated manufacturing.**

injection molding, continuous Molding parts by using continuously operating extruders. The extruders melt the plastic and use different techniques to deliver the melt into mold cavities. These continuous screw-rotating machines use many molds. The molds are usually located on a rotating circular table that can operate as Ferris wheels and carousels. Feeding a melt (through special nozzle adapters to the contour of the molds) onto a rotating mold has been applied since at least the 1940s. Products made include shoe soles, shoe sandals, and boats. See **Velcro strip.**

injection molding, controlled-density A process that uses a variable-volume mold cavity with a movable wall or plug type section in the wall. After filling the cavity with melt the cavity is compressed by the movable wall or plug. With foam molding, controlled solid skins with core are achieved. It is an adaptation of the injection-compression technique. See **injection-compression molding.**

injection-molding controller See **computer, microprocessor control; control actuator; die head, programmed; melt-temperature effectiveness; process control.**

injection-molding counterflow To eliminate or reduce weld lines, two separate injection units are used to move melt in and out of the cavity. Melt from one unit flows through the cavity and into the secondary unit. This type of action repeats and is programmed to enhance melt-flow patterns. See **weld line.**

injection molding cycle time A reasonable formula to use, regardless of the plastic processed, is the average wall thickness (in thousandths of inches decimal form) multiplied by 250. See **cycle.**

injection-molding cycle time, shortened Shortening cycle time requires assessing all the difficulties of the IM process during design of the part and the mold. Thus what is needed is a device for achieving optimum designs of part and mold. Program systems that provide for computer simulation of the IM process are used for this purpose. Relevant software programs provide guidelines and reduce cycle time by evaluating the actual IM process operational settings. See **cycle.**

injection molding degassing See **injection molding venting; mold breathing.**

injection molding degating See **mold-gate degating.**

injection-molding doser See **doser.**

injection molding, double-daylight A process that combines hydroelastic metal forming on the moving platen and a hot runner injection molding system on the fixed platen (Arburg GmbH). A center mold plate separates the two processes and is supported by guide arms on the tiebars. During processing a robot loads a metal blank into the hydroform section and moves the shaped blank from the previous cycle to the IM side. The mold's closing action drives the hydroforming process, and the already shaped blank is overmolded with plastics.

injection molding, double-shot See **molding, double-shot.**

injection-molding electrical cable "button" See **electrical cable "button."**

injection molding, foamed-gas counterpressure An air-tight sealed mold can be pressurized to 400 to 500 psi (2.8 to 3.5 MPa) with an inert gas, usually N_2, or enough pressure to suppress foaming as the plastic mix enters the cavity. After the measured shot is injected, pressure is released, allowing the instantaneous foaming to form a core between the already formed solid skins. See **injection molding, gas-assist.**

injection molding, foamed high-pressure The plastic mix is injected into the mold, creating a cavity pressure that is higher than the blowing-agent gas pressure; usually much higher ranging from 5,000 to 20,000 psi (34.5 to 138 MPa). As soon as the part skin surface hardens to the desired thickness, cavity melt pressure is reduced to produce a foamed core. Different techniques are used to release pressure, such as withdrawing core pins in the cavity or by special press motions that partially open the mold halves using two-dimensional or three-dimensional motions. See **injection-compression molding; injection molding, foamed low-pressure coinjected.**

injection molding, foamed low-pressure Low-pressure or short-shot conventional IM are the most commonly used because they are easy and simple to operate, particularly for large, complex, three-dimensional parts. The usual cavity pressure is 200 to 500 psi (1.4 to 3.5 MPa). An accumulator can be used between the plasticator and mold, providing a means of injecting a very large shot. Since low pressures are used, the part's surface appearance does not approach those processes using the higher pressures. Attractive surface patterns can be molded, such as swirl. See **accumulator; blow molding, extruder (intermittent).**

injection molding, foamed low-pressure coinjected Using the coinjection procedure, a solid melt is injected to form the solid, smooth skin against the cavity surface. Simultaneously a second short-shot melt with blowing agent is injected to form the foamed core. With a full second shot, the mold can incorporate pins or a mold that opens like high-pressure foam molding. See **coinjection molding; injection molding, foamed high-pressure.**

injection molding, foamed sandwich See **injection molding, sandwich.**

injection molding, foamed structural-web See **molding, structural-web.**

injection molding freeze-off See **freeze-off.**

injection molding, fusible-core See **injection molding, soluble-core.**

injection molding, gas-assist (GAIM) A process that uses a gas, usually nitrogen with pressures up to 3,000 psi (21 MPa), with the melt in the mold so that channels are formed within the melt. Gas can be injected through the center of the injection-molding machine nozzle as the melt travels to the cavity, or it can be injected separately into the mold cavity. In a properly designed tool, run under the proper process conditions, the gas (with a vicosity that is much lower than the melt) remains isolated in gas channels of the part without bleeding out into any thin-walled areas in the mold, producing a balloonlike pressure on the melt. The gas channels are areas that have been thickened to achieve functional utility in the part or to promote better melt flow during cavity filling. This action provides a high degree of packing the melt against the cavity walls. Gas pressure is held until the melt solidifies. This coring action reduces cycle time and the quantity of plastic used, develops a more structurally sound part (increases section stiffness), improves surface flatness, and reduces warps and sinks over thick sections. Thick parts can easily be made without voids or sink marks. See **GAIM software; injection molding, gas-counterflow; nitrogen; pressure, Lavell.**

injection molding, gas-assist without gas channel The Battenfeld Airmould Contour process provides a gas-assist alternative when it is not possible to inject gas directly into the molten plastic or where moldings with gas-channel openings are not desirable. It can be used where parts require only one smooth or high-gloss surface with a different wall thickness or complex geometry on the other side. The process has gas enter between the melt and mold-cavity surface where external pressure is applied to the melt. The gas can be applied within specific part sections.

injection molding, gas-counterflow A conventional IM system is used with a separate entrance to the mold cavity providing gas (usually nitrogen) pressurization prior to injecting the melt shot. This back pressure action can provide an even distribution of melt packing during its cooling cycle. When producing foamed plastic parts, this gas back pressure prevents the blowing agent from expanding until its part skins form followed by releasing (venting) the gas pressure. Controlled foam expansion is provided. See **injection molding, foamed-gas counterpressure.**

injection molding, gas-external See **injection molding, gas-assist without gas channel.**

injection molding heat-transfer mechanism See **heat-transfer mechanism.**

injection-molding holding pressure During the initial mold-filling phase of the molding cycle, high injection pressure may be needed to maintain the desired mold filling speed. Once the mold is initially full, then the cycle enters its holding phase, and the screw acting as a ram pushes into the mold cavity extra melt to compensate for material shrinkage. This may be done at a lower, second-stage pressure or, at the same initial high, filling pressure; this high pressure may not be necessary or even desirable. In many cases, a lower second-stage pressure therefore follows a high first-stage pressure. However, when molding some crystalline plastics, such as nylon and acetal, then the use of the second-stage pressure may not be desired because abrupt changes in pressure can cause undesirable performance changes in the molded part. See **injection molding, boost cutoff or two-stage control.**

injection-molding hollow part See **molding, die-slide.**

injection-molding infrared temperature control IM is a thermal process whose major task ultimately is to control temperature. Too much or too little heat at the wrong place can cause problems (short shot, galling, splay, brittleness, plastic degradation, etc.). You cannot see this thermal energy, only its effects. Thermal energy radiates in the infrared spectrum, outside the spectrum of visible light. Use has been made of IR video cameras to detect energy color patterns in all locations around the IM machine and auxiliary equipment. With this IR thermography, every plastic has its own wavelength, and temperature readings are related to the IR color patterns. IR signatures are also provided for each plastic using the Fourier transfer infrared spectrum (FTIR). See **infrared; spectroscopy, Fourier's transfer infrared.**

injection molding, in-mold Performing operations such as decorating, assembly, painting, labeling, and lamination in the mold usually can result in cost savings compared to postmold operations. Some part designs require materials that do not share any adhesive properties. In these cases, in-mold assembly not only allows use of such incompatible materials but also facilitates molding parts with movable joints in a single fabricating step. With plastic labeling, which includes thermoformed film, there is a possibility of adding strength to the product so that a thinner wall is molded. See **coating; coating, in-mold decorating, labeling; decorating; decorative sheet; foil decorating; injection molding, back-molding; injection molding, two-shot; thermoforming.**

injection molding, insert See **insert molding.**

injection molding, integral-hinge See **design hinge, integral.**

injection molding, intrusion When shot size is not large enough, prior to injecting a prepared shot in the plasticator, the screw is turning, which permits melt to enter the cavity followed by injecting the shot.

injection molding, jet A process in which the main heating to melt the plastic occurs when it passes through a nozzle or jet, rather than the more conventional process using a plasticator to melt the plastic.

injection molding, jetting Melt that enters the cavity, is in turbulent flow rather than in laminar flow. Causes include undersized gate and a thin to thick cavity section, resulting in poor control of the molded part. See **coolant, turbulent-flow; melt flow, laminar.**

injection molding, linear velocity displacement transducer (LVDP) A transducer that is used for measuring relatively small amounts of movement in the vertical or horizontal plane. The amount of movement is detected by means of a change in an electrical signal caused by the movement of an iron core within a coil; this change is then amplified and converted into a linear measurement. Very accurate readings of tie bar extensions can be obtained when using these devices. See **linear variable differential transducer; transducer.**

injection molding, liquid (LIM) A process that involves proportioning, mixing, and dispensing two liquid plastic formulations. This compound is directed into a closed mold. It can be used for encapsulating electrical and electronic devices, decorative ornaments, medical devices, auto parts, and so on. It is similar to reaction injection molding (RIM) in that it uses a mechanical mixing rather than a high-pressure impingement mixer. Flushing the mix at the end of a run is easily handled automatically. Plastics that are used include silicones and acrylics. Using a spring-loaded pin-type nozzle helps avoid liquid-injection hardware from becoming plugged with plastics. The spring loading allows you to set the pressure so that it is higher than the pressure inside the extruder barrel, thus keeping the port clean and open. Also called *reaction injection molding* (RIM). See **embedding; encapsulation; reaction injection molding.**

injection molding machine A machine designed for injection-molding plastics. See **injection molding machine, vertical.**

injection molding machine adapter section A section that fits on the end of the barrel and whose inside taper matches the taper of the tip of the screw so that there is a smooth flow of plastic toward the nozzle. See **adapter system.**

injection molding machine, adiabatic See **adiabatic; extruder, adiabatic.**

injection molding machine alignment See **machine alignment.**

injection molding machine ball-check valve A type of nonreturn valve at the end of the plasticating screw in which plastic melt can flow forward past the ball during screw rotation. The ball moves back and seals the passage during injection. See **injection molding machine ring check valve; screw tip, injection.**

injection molding machine barrel See **barrel, extruder and injection molding; barrel flange, front.**

injection molding machine barrel and feed unit See **barrel and feed unit.**

injection molding machine barrel heater Electric heaters surrounding the barrel. They are used to heat the barrel for start-up and provide some heat to the plastic during molding. See **heater band.**

injection molding machine characteristic IMMs are characterized by their shot capacity (shot represents the maximum volume of melt that is injected, which usually is about 80% of the actual volume of the machine's capability; the difference provides a backup safety factor for packing), rate of injection, injection pressure, and clamp pressure with mold-locking force. Shot-size capacity may be given in terms of the maximum weight that can be injected into a mold cavity and usually is quoted in ounces or grams of general purpose PS (GPPS). A better way to express shot size is in terms of the volume of melt that can be injected into a mold at a specific pressure. Rate of injection relates to its speed and also the control capability of cycling the melt to move fast-slow-fast, slow-fast, and so on. See **injection molding machine shot size.**

Injection pressure in the barrel when the shot is injected can range from 2,000 to at least 30,000 psi (14 to 205 MPa). The characteristic of the plastic being processed defines what pressure is required in the mold to obtain good parts. Based on what cavity pressure is required, the barrel pressure has to be high enough to meet pressure-flow restrictions going from the plasticator into the mold. Clamp pressure required in the IMM depends on the plastic being processed. It requires a specified pressure in the mold cavity. It is basically the cross-sectional area of any melt that is located on the parting line of the mold, which includes the cavities and the thermoplastic cold runner that is located on the parting line. The thermoplastic hot melt that is located within the mold is not in the parting line. By multiplying the pressure required on the melt and the melt cross-sectional area, the clamping force required is determined. A safety factor is provided by a 10 to 20% increase. See **mold runner.**

injection molding machine clamping See **clamping; clamping platen, floating; clamping platen, stationary; clamping platen, shuttle; clamping pressure, injection molding machine; clamping, tie barless; mold, stack.**

injection molding machine control See **injection molding machine-drive system.**

injection molding machine conventional nozzle A nozzle with a straight hole leading to the screw bushing. See **screw tip, injection.**

injection molding machine daylight The distance between the mold platens. Maximum daylight is the maximum distance they can separate. See **clamping, daylight-opening.**

injection molding machine downsizing Very few of the installed IMMs run shot sizes anywhere near the full shot size capacity of the injection unit. Typical usage is from 25 to 60%, but in many cases it is even less. Most suppliers of IMMs offer several sizes for any given clamp tonnage. At the time of purchase, the thinking regarding the injection unit is to "make sure we have enough." The problem of having too much shot capacity can render some machines unusable for certain materials and applications. One related problem is excessive residence time, which causes degradation of the plastic; this situation exists for most engineering plastics. Another problem with very large injection units and small shot sizes is relative to the plasticating screw design. To properly plasticize the plastic, the screw should impart about 40% of the energy that is needed to melt the plastic via the drive motor. If the screw rpm is too low and the screw's metering zone flight depth is too deep relative to the throughput needed, very little energy will come from the screw drive, resulting in a poor melt mix leading to poor part quality. One solution is to purchase a completely new, smaller injection unit. Another, usually less expensive, is to downsize the existing injection unit. Often it is possible to utilize greater injection pressures. Consideration to limiting torque to the hydraulic screw drive motor should also be given to reduce breakage of the smaller screws to be used. See **barrel downsizing and upsizing; drive-system control; injection-molding machine upsizing; residence time; screw; screw design.**

injection-molding machine downtime See **processing-line downtime; processing-line uptime.**

injection-molding machine-drive system There are basically three different systems: hydraulic, electrical, and hybrid. The hybrid drive is a combination of hydraulic and electrical. At present the hybrid system provides a technically effective and economically reasonable compromise. At the current pace of electrical drive developments, more economical and efficient electrical drives will make them more acceptable. See **design, motion-control, mechanical and electronic effects; drive-system control; electric motor; injection molding machine electrical operation; injection molding machine hydraulic operation; servo control-drive reliability.**

injection molding machine control See **controlled motion; process control.**

injection molding machine electrical operation Electrical IMM designs are based on energy efficiency, high power, variable-controlled power, and brushless motors. A major use continues to be electrical-hydraulic hybrid IMMs. Electrical systems (compared to hydraulic systems) have certain advantages, including cleanliness by elimination of oil fluid problems, closed-loop liquid cooling, no need for extensive air conditioning, dynamic braking resistors, quick start-up and set-up, molding quality, productivity, repeatability without operator attention, and low noise level (below 70 dB). Its simpler solid-on-solid power train eliminates the major causes of molding variations in hydraulic oil IMM with all its hardware. A hydraulic system includes a motor, coupling, pump, hoses, filter, valves, tubings, heat exchanger, and tank; an electric system includes servomotors, pulleys, belts, and ball-screws.

See **design, motion-control, mechanical and electronic effects; drive-system control; electric motor; electric-motor drive; extruder drive-energy consumption; injection molding machine-drive system.**

injection molding machine energy saver See **electric motor, adjustable-speed-drive; energy input, machine; energy loss, machine.**

injection-molding machine fabricator process simulator See **process simulator.**

injection molding machine feed zone See **screw feed zone.**

injection molding machine gear pump See **gear pump.**

injection molding machine high-volume pump A hydraulic pump that is used to pump a large volume of oil into the injection cylinder quickly during injection of the melt.

injection molding machine hopper See **hopper.**

injection molding machine hydraulic clamp See **clamping, hydraulic.**

injection molding machine hydraulic injection cylinder A cylinder into which oil is pumped under pressure to force the injection piston and plasticating screw forward.

injection molding machine, hydraulic operation of IMM with an oil hydraulic system provides the power to turn the screw to plasticate the plastic, inject the melt into the mold cavity, close the mold clamp, hold clamp tonnage, release the clamp, and eject the molded part. A number of hydraulic components are required to provide this power, including motors, pumps, directional valves, fittings, tubings, and oil reservoirs/tanks. See **drive-system control; hydraulic fluid influenced by heat.**

injection molding machine hydromechanical clamp See **clamping, hydromechanical.**

injection molding machine length-to-diameter ratio See **screw length-to-diameter ratio.**

injection molding machine locating ring A ring that aligns the nozzle of the plasticator cylinder with the entrance of the sprue bushing in the mold. See **mold sprue.**

injection molding machine lockout See **safety, machine-lockout.**

injection molding machine low-volume pump A hydraulic pump that is used to maintain pressure on the plastic until the gate freezes.

injection molding machine maintenance Maintenance decreases or eliminates downtime and optimizes performance. The machine operator or the maintenance personnel can follow the manufacturer's maintenance procedures according to a firm schedule for maintenance. The IMM must be properly shut down when any maintenance (or inspection) that can cause injury is performed. See **inspection; maintenance, preventive; processing-line downtime; troubleshooting.**

injection molding machine melting capacity The amount of a plastic that can be melted per hour by the machine under specified operating conditions. See **melt.**

injection molding machine metering zone See **screw metering zone.**

injection molding machine mixing section See **screw mixing section.**

injection molding machine mold See **mold; mold, preengineered.**

injection molding machine nonreturn valve A one-way valve at the tip end of the plasticator that permits plastic melt to flow in one direction and closes to prevent melt back flow. See **screw tip, injection.**

injection molding machine nozzle The orifice-containing end of a heating barrel that connects the injection unit to the mold through a platen.

injection molding machine nozzle drooling An undesirable situation where leakage from or around the nozzle area during injection occurs. The problem can occur when plastic is trapped between the nozzle and mold bushing.

injection molding machine nozzle extended A nozzle that extends into the mold.

injection molding machine nozzle freeze-off See **freeze-off.**

injection molding machine nozzle gate See **mold-gate nozzle.**

injection molding machine nozzle shut-off A nozzle that incorporates some type of valve to prevent leakage when melt is not to be injected into the mold. See **screw tip, injection.**

injection molding machine operation See **fabricating startup and shutdown.**

injection molding machine plasticating screw See **screw plasticator.**

injection molding machine plasticator wobble See **plasticator wobble.**

injection molding machine platen See **clamping; platen.**

injection molding machine process control See **process control.**

injection molding machine programmable controller safety See **programmable-controller safety.**

injection molding machine, ram An IMM that uses a ram inside of a heated barrel rather than the conventional screw. The plastic inside the heated barrel develops additional heat as it usually moves by a spreader. The plunger moves forward, forcing the melt into the mold cavity. Also called *plunger IMM* or *plunger injection molding.* See **extruder, ram; injection molding ultrahigh-molecular-weight polyethylene; ram; spreader.**

injection molding machine, reciprocating-screw A conventional type of IMM where plastic is melted using a combination of conductive heat from heater bands surrounding the barrel and frictional heating created by a rotating screw inside the barrel. The screw reciprocates back to allow melted plastic to accumulate ahead of it and then moves forward, injecting the melt into the mold all in one stage. The accumulation of melt at the screw tip forces the screw toward the rear of the machine until enough melt is collected for a shot. The required low back pressure on the screw is used during this plasticating action, and when the shot size is produced, the screw stops rotating. As soon as the mold has ejected its molded part and closes, the nonrotating screw acts as a plunger and "rams" the melt into the cavity using very high injection pressure. The advantages of the reciprocating-screw IMM compared to the two-stage IMM include the following: (1) reduced residence time, (2) self-cleaning screw action, and (3) possibly more accurate and responsive injection control. These advantages are key to processing heat-sensitive plastics. Also called *injection molding machine, single-stage.* See **injection-molding machine, two-stage.**

injection molding machine ring check valve A type of nonreturn valve at the end of the screw in which a ring slides forward and back. When the screw rotates, melted plastic can flow past the ring and through slots around the valve. But during injection the ring moves back, stopping the back flow of the melt. See **injection-molding machine ball-check valve; screw tip, injection.**

injection molding machine, rotary See **clamping platen, rotary.**

injection molding machine safety See **barrel venting safety; safety and machines; safety interlock.**

injection molding machine safety gate The door that the operator opens and closes to reach the mold or molded products. An electrical interlock, a hydraulic interlock, and a mechanical safety bar keep the IMM from cycling if the safety gate is open. See **safety gate and screen guard; safety, machine-lockout.**

injection molding machine sales Worldwide sales of IMM equipment, practically all hydraulic systems, is approximately $10.5 billion per year (in the United States it is $3.5 billion per year) with 30% in machines, 60% in molds, 6% in robots, and 4% in hot runners. The market is 55% technical products (electronic, mechanical, medical, etc.), 20% automotive, 10% packaging, and 15% others. Worldwide approximately $180 billion per year sales exist for injection-molded products, with 50% using PET plastics (includes injection blow molding), 30% other plastics, and 20% closures. See **market; plastic consumption; plastic industry machine sales.**

injection molding machine screen pack See **screen pack.**

injection molding machine screw See **screw.**

injection molding machine screw drive A servoelectric drive can be used to provide screw rotation that is independent of other machine functions, replacing the more conventional hydraulic drive at a significant operating energy savings. This more expensive drive allows screw recovery simultaneously with other machine functions. See **drive-motor control; electric motor; hydraulic.**

injection molding machine short shot See **shot, short.**

injection molding machine shot size The amount of plastic that the IMM injects into a mold during one injection stroke. This amount ranges from less than an ounce (milligram) to hundreds of pounds. The usual range is from a few ounces to 10 lb. Superlarge IMMs have been built. In the past Billion of France built a three-platen, four-tiebar, conventional central hydraulic clamping unit 10,000-ton IMM with a shot size of 390 lb (177 kg) using three injection units that were 100 ft (30½ m) long with 16 by 8 ft (5 by 2½ m) platens. More recently, Husky of Canada built a two-platen, eight-tiebar, clamping cylinder on each tiebar 8,800-ton IMM with a shot size of 140 lb (64 kg) using single (200 mm screw diameter) or dual (170 mm screws) injection units that were 1.8 by 1.5 ft (6 by 5 m). See **injection molding machine characteristic; injection molding, micro-.** When reviewing shot size, the proper selection of screw diameter and length-to-diameter ratio is critical to the manufacture of parts, especially high-quality parts at economical cycle times. Generally, 25 to 60% of a four-diameter full stroke on a 20/1 L/D screw is considered a good operating range. This is appropriate when recovery time is approximately 50% of the overall cycle and given a screw and barrel combination with proper design to melt or mix the succeeding shot. See **screw length-to-diameter ratio.**

injection molding machine, single-stage See **injection molding machine, reciprocating screw.**

injection molding machine tie bar growth Unbalanced heat of tie bars can directly influence mold performance, particularly at start-up. If the heat differs from top to bottom bars, different expansion can occur. Insulating between mold and platen can help as well as recording (sensors) any growth changes that may occur.

injection molding machine, tie barless See **clamping, tie barless.**

injection molding machine tie bar measurement Using an instrument (such as strain gauges) that is mounted on or at the end of tie bars to measure any pressure imbalance on the mold due to imbalance in applied clamping pressures via the tie bars. See **measurement; strain gauge.**

injection molding machine, toggle clamp See **clamping, toggle-action.**

injection molding machine, two-stage An IMM that uses a fixed plasticating screw (first-stage) to feed melted plastic into a chamber (second-stage). After the second-stage receives its shot size, a plunger then forces the melt into a mold. Its first stage is a continuous extruder. A diverter valve has three positions. The first position is having it closed facing the extruder while it is preparing the melt. The next position directs the melt from the extruder into an accumulator. Its third position directs a shot of melt from the accumulator into the mold cavity. During all this action, which occurs within seconds, the extruder (first-stage) continues to operate and to produce melt. When the melt is not being directed into the accumulator, it remains in the barrel, which could build up a slight pressure for a short time period. The extruder is designed so that the screw can have some motion in moving back for melt to accumulate in the front of its barrel without any major buildup of pressure. It is also designed so that controls can be set to avoid damage to the melt. Also called *preplasticizing IMM.* See **accumulator; injection molding machine, reciprocating screw.**

When compared to the reciprocating-screw IMM, the advantages of the two-stage IMM include (1) consistent melt quality, (2) ram action in the accumulator that provides high injection pressure very fast, (3) very accurate shot-size control, (4) product clarity, and (5) easily molded very thin-walled parts. Its disadvantages include higher equipment cost and increased maintenance. See **injection molding, micro-.**

injection molding machine upsizing Upsizing can be done to increase shot size. A number of items have to be considered, such as barrel-wall thickness, resultant screw length-to-diameter ratio, injection-speed reduction, screw-drive torque, and injection pressure drop. Before considering the upsizing process, one has to determine whether the molds can be filled properly using decreased pressures and injection speeds; they will decrease directly proportional to the difference in the barrel ID projected areas. Also to be included are factors such as the screw L/D. See **barrel downsizing and upsizing; injection molding machine downsizing; screw length-to-diameter ratio.**

injection molding machine vented See **screw, venting.**

injection molding machine, vertical A plasticator barrel that is in the vertical position rather than the usual horizontal position. About 5% of the dollar value of IMMs are of vertical design. Their major use is for manually or, more often, automatically fed insert molding and dissimilar plastic materials molding. Mold systems that are used include shuttle types and rotary tables.

Injection Molding Magazine See **World of Plastics Reviews: Molding Our Future Vision.**

injection molding marbleizing See **screw marbleizing.**

injection molding material consumption See **plastic consumption.**

injection molding material handling See **material handling.**

injection molding melt blockage See **extruder melt blockage.**

injection molding melt cushion A layer of melt that is just a few mm (0.04 in.) thick and is maintained between the screw tip and the nozzle as the stroke is completed and the mold fills. It keeps the plastic melt injected into the mold under pressure during its shrinkage and until solidification occurs. It results in greater compactness and lower shrinkage of the molded part. See **cushion.**

injection molding melt extractor A type of device, such as a spreader (also called *torpedo*), that is placed in a plasticizing system for the purpose of separating fully plasticated melt from partially molten plastic. See **spreader.**

injection molding melt flow The flow of melted plastic into its mold. It is controlled by the injection unit's plasticizing capability melt pressure, and screw position. When hot runners are used, their valve gates are involved. Sequential valve gating has become important in some multigate applications. Thus these gates can be opened at different times during injection, increasing control over weld-line location and fill balancing. With an open-loop process, the injection unit is tied to the valve gates from the start of the injection by either the time or screw position. Once the valve is opened, the flow rate is completely controlled by the injection unit. The so-called dynamic-feed close-loop system uses variable flow valves. Each valve's position is controlled in response to the pressure requirement that is made downstream of the valves. See **injection molding process-control parameter; injection molding melt-shear behavior; melt flow; mold-cavity melt-flow analysis; mold-cavity melt fountain flow; mold-filling monitoring; mold gate, valve feed control.**

injection molding melt-flow oscillation Various oscillation techniques are available. The Scorim Process (Cinpres-Scorim) multilive feed molding process where two packing pistons oscillate 180° out of phase and eliminate weld lines, etc. The Rheomolding Process (Thermold's) system provides three-dimensional orientation based on the concept of melt rheology as a function of vibration frequency and amplitude as well as temperature and pressure. The equipment utilizes piston-type melt accumulators set up adjacent to the melt stream of the plasticator. The piston oscillates back and forth. The Press Alpha Process (Sumitomo Heavy Industries and Sankyo Chemical Engineering of Japan) system uses compression pins that are actuated when the cavity fills. These pins protrude into the cavity and begin oscillating to create localized compressions. The action eliminates weld lines, sinks, and warpage, reduces filling pressures, localizes thin-wall molding, and allows for gate positioning flexibility. See **extruder melt-flow oscillation; injection molding, vibrational; melt-flow oscillation; weld line.**

injection molding melt-flow test See **test, melt-index.**

injection molding melt, frozen layer See **mold cavity, frozen-layer.**

injection molding melt mixer See **static mixer.**

injection molding melt-packing factor See **injection molding melt cushion.**

injection molding melt-pulse cooling Cooling in which the coolant flows only after the melt fills the cavity rather than continually. Solenoid-controlled valves that are placed in the incoming coolant liners are used to open or shut off the coolant. Thus when the melt enters the mold, it is not subjected to a fast cooling shock. See **mold cooling, pulse.**

injection molding melt-shear behavior The melt shear rate in the gate can be very high. The melt pressure flow that establishes the shear rate can produce a rate in a pin gate in excess of 100,000 sec^{-1} in extreme cases. Typically it is from 1,000 to 10,000 sec^{-1}; in runners 10 to 1000 sec^{-1}; in cavities 0.001 to 100 sec^{-1}. Local flow rates and shear rates are constantly changing during filling and vary in direct relationship to the channel depths and the cross-sectional area for flow. Added to this variation is the highly transient nature of the process, with the melt pool at rest in the barrel prior to injection; between rest periods the melt is rapidly accelerated and decelerated. See **injection molding melt flow; melt-shear rate; orientation, accidental; shear rate, melt.**

injection molding melt temperature See **injection molding, programmed; melt temperature; temperature controller.**

injection molding melt-temperature effectiveness See **melt-temperature effectiveness.**

injection molding melt-temperature sensitivity See **temperature sensitivity.**

injection molding melt tracer See **tracer.**

injection molding melt vibration See **melt vibration.**

injection molding melt-weld line See **weld line.**

injection molding metal See **injection molding, nonplastic.**

injection molding, micro- The precision molding of extremely small parts and components, usually in engineering plastics that are unfilled, filled, or reinforced. Parts usually weigh less than 20 milligrams (0.020 g), with some even less than one mg. Molding small parts requires material to be moved in and out of cavities fast so that degradation does not occur. IMMs operate at very high injection pressures. Cycle times typically are about 2 to 8 s. Parts are produced with zero flash. They mold using a Battenfeld GmbH three-stage injection machine (plasticating slanted screw, vertical dosing unit, and horizontal injection plunger). IMMs are in a clean-room enclosure for molding 0.8 mg acetal watch gears, 2 mg PC housing for hearing-aid implant, 16 mg glass-reinforced LCP automotive microswitch actuator pin, and so on. Care has to be taken in handling parts. Some parts are so small and lightweight that static electricity can make them float in the air. Injection molding in micron sizes can be performed in specially designed IMMs. Precision molding involves proper process control, particularly high-speed injection speed and residence time. Proper venting usually has to include precision venting in the cavity as well as possibly removing air prior to entering the cavity. Product handling has to be considered. Approaches used include floating air systems, parts placed on film carriers, and a molded-in carrier strip made of the same material followed with automated separation. See **injection molding machine shot size.**

injection molding mold See **mold; mold cavity, injection.**

injection molding mold bluing See **mold bluing.**

injection molding mold-cavity pressure One of the problems in monitoring and controlling melt pressure is that it is not a constant for all positions in the cavity. Pressure in the mold cavity varies significantly from the applied pressure (hydraulic, etc. pressure). It also varies with distance of flow and shape of cavity in regard to melt-flow pattern. The cavity pressure in a mold is actually a profile, usually with its highest pressure at the gate and lowest pressure at the end of the flow path. However, with proper balance of pressure, temperature, and time, a pressure profile can be made to be relatively even (if required). Another approach is to control the upstream cavity pressure and monitor the last point to fill so that the cavity-pressure profile can be maintained. This approach is utilized in intelligent mold systems. See **mold-cavity pressure; molding pressure, required; process control.**

injection molding mold, cosmetic specification See **molded-part cosmetics.**

injection molding, mold dehumidification See **mold dehumidification.**

injection molding, mold gate-nozzle See **mold-gate nozzle.**

injection molding multilive feed See **injection molding melt-flow oscillation.**

injection molding, nonplastic IM methods such as metal injection molding (MIM), ceramic injection molding (CIM), and powder injection molding (PIM). Since at least 1940, IM nonplastics have been in existence. They include aluminum, ceramics, concrete, copper, dynamite, food, magnesium, stainless steel, wood, zinc, tungsten carbide, and other alloys of metals. Most materials are in fine powdered form. These green materials are usually used with plastic binders. Precision and complex parts are usually small in size. The green material can have a high bulk density of about 50 to 70wt% of their solid counterpart material. Binders can be removed using heat, solvent, or their combinations to purge or remove most of the plastic. The parts also can be sintered in a vacuum furnace to fuse the metal particles. Fusing causes the parts to shrink isotropically to achieve a 95 to 99% density. The first development of plastic IM was adapted from the die-casting machinery (using a much lower-temperature melting pot). See **blow molding metal; sintering; Thixomolding.**

injection molding nozzle-dispersion disc mixer A melt distributive and dispersive mixing device of various shapes and sizes that is installed between the endcap or nozzle adapter and nozzle tip. Mixers can be round discs with holes through which the melt can pass. Due to increase in shear, low-viscosity plastics tend to be used. Color change usually requires changing the mixer to ensure that there will be no contamination. See **mixer, disc; screw, barrier; screw mixing and melting.**

injection molding nozzle-plate dispersion plug Two perforated plates that are held together with a connecting rod and are placed in the nozzle to disperse a colorant or other additive in a plastic as it flows through orifices in the plates. This action is one of the methods taken when proper mixing does not occur during conventional IM. See **dispersion.**

injection molding nozzle-pressure control During the initial mold filling of the cycle, high injection pressures may be needed to maintain the desired mold-filling speed. Once the mold is filled, then this high pressure may not be necessary or even desired. If a second-stage holding pressure is required, then a signal that initiates the changeover must be generated. Changeover at the velocity pressure transfer (VPT) point may be set or triggered in various ways, such as a nozzle-pressure control (NPC) or as melt pressure control (MPC). See **controller.**

injection molding operation optimization To minimize costs and improve technical quality, continuous monitoring and optimizing of the manufacturing process is required using a systematic approach to production, such as the FALLO approach. Faults and changes in ambient conditions, materials, IMM variables, and mold wear involve a constant reexamination of the process operational settings. See **FALLO approach; process control.**

injection molding operator's sequence See **operation, automatic; operation, manual; operation, semiautomatic.**

injection molding packing mold See **cushion; injection molding melt cushion; mold-filling monitoring.**

injection molding packing time The amount of time that packing pressure is kept by the screw until the gate freezes off.

injection molding part orange peel See **orange peel.**

injection molding part shrinkage See **blow molding shrinkage; design shrinkage; molding shrinkage; shrinkage; shrinkage block jig; tolerance and shrinkage.**

injection molding plastic At least 90wt% of all IM plastics are thermoplastics, but IM parts include combinations of TPs and thermosets as well as rigid and flexible TPs, reinforced plastics, and elastomers. During IM the TPs reach maximum heat during plastication before entering the mold. The thermoset plastics reach maximum temperatures in the hot molds. If too much heat develops during plastication, the TPs solidify, and the IMM stops, requiring cleanup. See **elastomer; injection molding, two-shot; injection molding ultrahigh-molecular-weight polyethylene; material handling; thermoplastic; thermoset plastic.**

injection molding plasticator See **plasticator; screw length-to-diameter ratio.**

injection molding, plunger See **injection molding machine, ram.**

injection molding, pressure required See **injection molding melt cushion; molding pressure, required; pressure, locking.**

injection molding printed-circuit board See **injection molding circuit board.**

injection molding process control The process of making an IM product includes three key ingredients—sufficient dynamic performance, sufficient repeatability, and proper control parameters. A lack of these ingredients can result in unacceptable products, higher scrap rate, longer cycles, and higher part cost. Conventional systems are generally designed for closed-loop control parameters such as injection velocity, holding pressure, cushion, and recovery stroke. Other parameters to be considered include melt temperature and cavity temperatures that affect and relate to the important condition of the consistency of the molded part. See **control actuator; die head, programmed; molding-process control; microprocessor control; process control.**

injection-molding process-control fill and pack Boost-time variation is eliminated by removing the boost timer and replacing it with something that is sensitive to the occurrence of the operation following fill. At this portion of the cycle, the mold will be essentially filled, and any further filling will result in extensive compression of the melt. Plastic compression is necessary for good part quality, and must be controlled. As compression results in a dramatic rise in pressure, sensing this instrumentation pressure rise will place the end of fill at its proper time without the use of a timer.

injection molding process-control-drive optimized See **control drive, optimized.**

injection molding process-control parameter IM machine settings are linked with material status variables in the process to intercept not only machine but also material induced variations in product properties. Changes in processing parameters are identified and corrected in two ways: (1) during the injection phase via the injection operation and (2) during the follow-up pressure and cooling phase from pressure-volume-temperature status curve. The selected intervention point, the sensors used, and the control elements act in conjunction with the microprocessor to determine the successful operation of the IMM. The starting point for successful molding is a melt that is thermally and mechanically as homogeneous as possible and has defined flow properties. The mold-filling operation is determined by melt viscosity. Knowing this value directly at the nozzle head is desirable. However, machine nozzles designed like capillary rheometers with several melt-pressure transducers are a future practical reality. Factors that cause this situation—including excessive residence time, shear fracture causing degradation, and very high injection pressure—militate against their practical use. Unlike extrusion, melt feed in IM does not take place under steady-state conditions. For this reason it is not realistic to expect a homogeneous melt, particularly with a long feed path, which can occur during extrusion. Depending on the plastic and screw design, axial melt-temperature profiles occur in the space in front of the screw. Generally large length-to-diameter ratios for the screw and feed paths shorter than 3.5 D reduce this effect. Screws with a diameter that is greater than 3.5 in. (90 mm) should be 20 to 24 D long, and those with a D less than 3.5 in. should be 18 to 20 D.

See **injection molding melt flow; melt flow; mold-cavity melt-flow analysis; residence time; rheometer; screw design; viscosity.**

injection molding process-control parting line A technique that controls the process by using movement between the two mold halves as the plastic melt is injected. This movement, using sensors on the outside of the mold, is used to transfer the injection to holding pressure control. See **mold-parting line.**

injection molding process-control safety See **programmable-controller safety.**

injection molding process-control variable To judge performance, there must be a reference to measure performance against. The mold-cavity pressure profile is a parameter that is easily influenced by variations. Related to this parameter are four groups of variables that when put together influence the profile: (1) melt viscosity and fill rate, (2) boost time, (3) pack and hold pressures, and (4) recovery of plasticator.

injection molding processing window See **processing window.**

injection molding product-surface measurement See **molded-material surface measurement.**

injection molding, programmed A method that provides a nonuniform melt-flow rate. It has many applications, primarily in thick molded parts, optical parts, and a variety of special applications where large size and complex shapes are used. If a mold can be used to make good parts in a conventional IMM, then programmed injection is not necessary. A better approach is to keep the injection rate consistent shot after shot. On a machine that is equipped with a mold-pressure control system, increased first-stage injection pressure can be used to overcome viscosity variations. A simple but effective pressure-compensated flow control can be used to control fill speed. The flow control can be set by observing fill time reading on the control system and adjusting a valve to set the correct reading. Fill time can be held to +/−1% using this simple and easy-to-process method. A servo valve base greatly reduces plastics flow-rate variations. See **injection-molding melt temperature; mold-cavity pressure; programmable-controller safety; test, melt-index.**

injection molding purging See **purging.**

injection molding, ram See **screw torpedo; spreader.**

injection molding, reaction See **reaction-injection molding.**

injection molding, reciprocating-screw See **injection-molding machine, reciprocating-screw.**

injection molding reinforced plastic Most IM products are thermoplastics. Practically all the reinforcement used is fiberglass. When processing with fiberglass in production, wear-resistant screws are needed. With continuous IM, these screws may become worn and need replacement in about six months. See **fiberglass; reinforced-plastic injection molding; screw wear.**

injection-molding safety See **safety.**

injection molding, sandwich A skin-core structure that is molded using multiple plasticating units that feed their percentage of the total shots to a single injection unit. These layers of plastic melts are injected sequentially into the mold. Because of the laminar nature of melt flow, these layers do not mix with each other. Included in the core can be a solid or foam structure. See **coinjection molding; injection molding, foamed-gas counterpressure; sandwich construction.**

injection molding screen pack Continuously operating screen-pack filters permit trouble-free use of recycled plastics by protecting sensitive mold-cavity surfaces against damage from foreign particles without interrupting the molding process. The screen pack is usually mounted against the nozzle side of the stationary platen. See **extruder screen pack; screen pack.**

injection molding screw pulling The screw can be removed from the barrel manually, which can be difficult and time-consuming, or it can be pushed out automatically by hydraulic or other action. The automatic approach eliminates the need for special extraction devices and reduces the chances of screw damage. See **cleaning; extruder screw pulling; screw removal; stripping fork.**

injection molding screw-rotation speed The screw is rotated to fill the cylinder or barrel with plastic material for the next shot. As the plastic is pushed forward and into the mold cavity, the screw acts as a ram and pushes the plastic melt. Some of the heat that is necessary to plasticize the material comes as a result of rotating the screw. The faster it rotates, the higher the temperature. Excessively high temperature causes slippage of the material with the temperature leveling off or reduced. Although higher speeds with higher heating are possible, it does not follow that a high screw speed should be used. The speed should be adjusted based on material and cavity-filling requirements. The lower speeds will give more uniform temperatures, reduce wear on the IMM, and reduce the residence time at the front-end of the injection cylinder. See **residence time; screw; screw design; screw rotation speed.**

injection molding screw suck-back The slight retracting of the screw that occurs after injection molding the melt, the part has solidified, and the mold is opening so that no drooling of the melt occurs out of the nozzle when it is retracted from the mold's sprue. Nozzle-temperature adjustment and type of nozzle used can eliminate this problem.

injection molding shot-size capacity See **injection molding machine shot size.**

injection molding shrinkage and tolerance See **mold-filling monitoring; shrinkage; tolerance and shrinkage.**

injection molding, sink mark See **sink mark.**

injection molding, soluble-core IM soluble or fusible cores make it possible to produce simple to complex hollow shapes. See **soluble-core molding.**

injection molding splay To avoid forming microscopic cavities in a molded part when processing thermoplastic materials, it is important to maintain a minimum, rather than maximum, pressure during injection of the melt. As the melt cools, the bubbles grow, which in turn can decrease mechanical and other properties of the part. Most cavities are formed as a result of water vapor that is present on the surface as well as imbedded in the plastic particles themselves. When these bubbles form on the surface, they are called *splay*. See **injection-molding venting; splay mark.**

injection molding starve feeding See **material starve feeding; venting feeder.**

injection molding static mixer See **static mixer.**

injection molding statistical assessment See **statistical assessment.**

injection molding tandem machine When a large enough IMM is not available or limited production exists, two IMMs can operate side-by-side in tandem. A large mold is located across both sets of platens.

injection molding temperature See **melt-temperature effectiveness.**

injection molding thermoset plastic See **screw, thermoset-type.**

injection molding troubleshooting See **troubleshooting.**

injection molding, two-shot Two materials are molded so that the first molded shot is overmolded by the second molded shot; the first molded part is positioned so that the second material can be molded around, over, or through it. The two materials can be the same or different, and they can be molded to bond together or not bond together. If materials are not compatible, the materials will not bond so that a product such as a universal or ball-and-socket joint can be molded in one operation. If they are compatible, controlling the processing temperature can eliminate bonding. A temperature drop at the contact surfaces can occur in relation to the second hot-melt shot to prevent the bond. Also called *overmolding, in-mold assembly, two-color rotary,* or *two-color shuttle*. See **clamping platen, rotary; injection molding back molding; injection molding in-mold; press, rotary.**

injection molding, ultrahigh-molecular-weight polyethylene (UHMWPE) A material that has superior properties, such as exceptional wear-resistance, and is usually press sintered, ram extruded, or ram injection molded. Usually semifinished parts that require secondary operations such as machining are molded. For long runs of fairly small parts (2 to 300 g) with complicated shapes, injection molding can be used, but this very highly viscous plastic can cause high pressure loss along the melt-flow path through the plasticator. Molecular orientation has to be taken into account when designing gates in the mold to meet the part geometry. High melt and mold temperatures are required. The high injection pressure should produce as high a melt-front velocity as possible, which will give rise to a local increase in temperature in the screw shear section. The high heat level facilitates the relaxation of molecular orientations. See **extruder, ram; injection molding machine, ram; polyethylene plastic, ultrahigh-molecular-weight; sintering.**

injection molding, vacuum The mold (via seals) is enclosed in a vacuum to remove unwanted gas by-products. See **vacuum.**

injection molding Velcro strip See **Velcro strip.**

injection molding venting Thermoplastics, particularly engineering plastics or hygroscopic types, absorb moisture during storage if not properly stored. Procedures for drying, storing, and handling these materials are used before being processed. Vented barrels also are used to remove moisture. Most of the vented barrels have a length-to-diameter ratio of at least 26. The longer than standard L/D (1) prevents reduction in the plastication of material (screw recovery), (2) prevents an uneven return stroke of the screw, (3) prevents extradition of the melt from the vent opening, and (4) provides proper plastication of the plastic without added shear. However, with experience and proper design, particularly of the screw, IMMs can be used with much shorter L/Ds. The molding operations that use vented barrels differ slightly from conventional IMMs. Factors to consider include minimizing screw back pressure, minimizing melt-temperature barrel profiles, rapidly applying heat to plastic on entering the barrel, and possible back flushing of the vent zone or pulling of the screw for cleaning when color or even material changes are made. See **barrel-venting safety; drying operation, hygroscopic plastic; hydrolysis; hygroscopic; screw length-to-diameter ratio; screw pump ratio; screw venting; venting; venting purifier.**

injection molding versus blow molding See **blow molding versus injection molding.**

injection molding versus thermoforming See **thermoforming versus injection molding.**

injection molding, vibrational The melt is subjected to a low-frequency vibration by using the machine's power system to oscillate its screw during injection or valving during the holding phase in the mold cavity. This action provides rheological control of the melt. See **melt vibration.**

injection-molding weld line See **weld line.**

injection molding with rotation See **blow molding, injection-with-rotation.**

injection molding, zero defect See **zero defect.**

initiator An additive that causes a chemical or physical reaction in the melt.

ink See **electrical corona discharge treatment; printing ink.**

ink and biodegradables See **recycled paper.**

ink, aniline A fast-drying ink that is used on polyethylene plastics.

ink, environmental See **environmentally acceptable coating, ink, adhesive reliability.**

ink wettable See **hydrophilic surface; ion-beam surface modification.**

inlay or overlay A layer that is applied to plastic fabricating processes such as moldings during or after molding. See **decal; film decorating; film, laminated; molding, film-insert.**

inlay printing See **printing, valley.**

in-line pouch with zipper See **thermoforming, form, fill, and seal.**

in-line processing See **processing, in-line.**

in-mold assembly See **injection molding, backmolding; injection molding, two-shot.**

in-mold coating, decorating, labeling See **coating, in-mold decorating, labeling.**

in-mold decorating The decorating of the plastic part while it is in the process of being molded (injection, compression, blow, etc.). Decoration includes printed film or foil that may be thermoformed or inserted in the mold manually or automatically. See **decorating; film decorating; foil decorating; injection molding, backmolding; molding, film-insert; tie layer.**

in-mold operation In-mold operations provide different advantages, such as protecting, decorating, or enhancing the surfaces of plastic parts, by applying decorative labels, painting or printing, hot embossing, laminating or flocking, and coating or metallizing. See **injection molding, in-mold; injection molding, two-shot; texturizing.**

in-mold paint coating See **paint coating, in-mold.**

innovative See **design, innovative; blow-molding innovation; creativity.**

inorganic See **organic; organic, in-.**

inorganic chemistry See **chemistry, inorganic.**

inorganic, plastic See **chemistry, inorganic; plastic, inorganic.**

in-place foaming See **foamed in place.**

input/output See **productivity.**

insert In mechanical fastening, an integral part of a plastic molding that consists of a metal, plastic, or other material that can be molded into the plastic or pressed into position after molding. See **design disassembly; joining; molded-in thread; stress, residual; welding.**

insert induction bonding The use of high-frequency electromagnetic fields to excite the molecules of metallic inserts that are placed in the plastics or in the interfaces, thus fusing the plastics when slight pressure is applied. The inserts remain in the joint. See **fusion.**

insertion, ultrasonic By the application of a vibratory mechanical pressure at ultrasonic frequencies, a metal insert is gently forced through a predetermined hole size in a thermoplastic, causing melting action. After insertion, cooling action results in a secure bond. See **sealing, ultrasonic.**

insert molding A process by which components such as pins, studs, terminals, and fasteners may be molded in a part to eliminate the cost of postmolding. Different processes are used, such as injection molding-vertical, compression molding, and casting. Considerable stresses can be set up in thermoplastic parts. To relieve stresses, parts are allowed to cool slowly during molding or are oven cooled or annealed after molded. Also called *molded insert.* See **annealing; fastener, mechanical; injection molding; mechanical holding load; molded screw thread; stress relieving; stress, residual; welding, forced bossed.**

insert, open-hole An insert with a hole completely through.

insert, threaded mechanical A metal, self-threading insert that has an exterior locking device for anchorage in the part to be joined. The threaded interior of the insert allows for repeated assembly and disassembly. Threaded mechanical inserts provide high-strength joining of plastics parts with low stresses.

Insite Dow Chemical's trade name for its ethylene family of plastics, which are produced using their metallocene catalyst polymerization technology.

in situ In the natural or original position.

Insituform See **sewer rehabilitation.**

insoluble Dissolvable in water to only a very small extent. See **water.**

inspection The process of measuring, examining, testing, gauging, or using other procedures to ascertain the quality or state, detect errors or defects, or otherwise appraise materials, products, services, systems, or environments to preestablished standards. See **automation, vision; injection-molding machine maintenance; maintenance; material received, checking; processor certification; quality control; quality system regulation; radiographic inspection; sampling plan; screw inspection; screw wear; sensor, dynamic accuracy; test, nondestructive acoustic-holography; test, nondestructive inspection; test, nondestructive ultrasonic penetration; test sample.**

inspection, infrared A nondestructive testing method that is practical for the manufacture, repair, and analysis of reinforced plastics under field conditions. It relies on changes in thermal conductivity that are caused by flaws or damage. It can also be used in studying the distribution of stress in parts. The test sample is subjected to a load, and an IR picture is taken with or without application of external heat. Also called *thermography.* See **infrared; strain, residual; test, infrared; test, nondestructive photoelastic stress-analysis; test, nondestructive temperature differential by infrared.**

inspection, vision-system Automatic vision systems are used to control the quality and productivity of plastic parts through inspection, gauging, flaw detection, verification, counting, character reading, identification, sorting, robot guidance, location analysis, adaptive control, and so on. See **automation, vision; computer image-processor; quality control.**

inspection, visual Visual and optical inspection should not be overlooked as important nondestructive test techniques. Low-power magnification lenses and microscopes can be used to advantage in improving visual inspection. Continuous online inspection and imaging systems are used for specific applications very successfully. Surface defects, voids, porosity, delaminations, plastic-rich or -starved areas, and contaminants are examples that may be detected, particularly with transparent plastics. See **automation, vision; test, nondestructive inspection; transmission, electron-microscope.**

instability See **melt instability.**

instrument calibration See **calibration.**

insulated electrical capacity See **permittivity, relative.**

insulated runner See **mold runner.**

insulation failure See **cable insulation water treeing.**

insulation, photoconductive plastic See **photoconductive plastic.**

insulation resistance Electrical or thermal insulation properties allow some plastics to provide a wide range of performances and meet many different industry requirements. Some plastics have such low electrical conductivity that the flow of current through them can usually be neglected. Similarly, materials of low thermal conductivity are used to insulate structures from below the earth, on earth, and up in space. Also called *insulator.* See **aerogel; alumina trihydrate; electrical insulation, askarel; electrical wheatstone bridge; foamed in place; permittivity, relative; temperature properties of plastics; test, conductivity.**

insulation R-value, heat A value that provides a measurement of the efficiency of an insulation regarding heat transfer.

insulator **1.** A material of such low electrical conductivity that the flow of current through it can usually be neglected; the insulator has significant electronic resistivity. See **electrical conductivity. 2.** A material of low thermal conductivity, such as that used to insulate buildings or cryogenic containers. See **aerogel; thermal capacity; Tyvek.**

insurance See **legal matter: Insurance Risk Retention Act; risk, acceptable; risk management.**

integral hinge See **design hinge, integral.**

integral skin See **foamed self-skinning.**

integrated circuit (IC) A semiconductor chip device. These one-piece components contain the equivalent of thousands of circuits etched in microminiaturized form on the surface of a chip. See **business card, electronic; electronic chip; packaging, electronic.**

integrated circuit, plastic An all-plastic experimental IC chip was made in 1998 by Philips (Eindhoven, the Netherlands). The base of the 15-bit programmable code-generator is a polyimide wafer that is fitted with 326 transistors and more than 300 vertical contacts. Semiconducting material is a conjugated polymer polyienylenvinylene that is used as the isolation component. The polyaniline conductive polymer constitutes the electrode. The transistor structures are created by masking the polyaniline and irradiating it with ultraviolet radiation to reduce conductivity by almost 10 orders of magnitude. See **plastic and the future.**

integrated-circuit reliability See **control-system reliability; reliability.**

integrated plant See **manufacturing execution system.**

intelligence The ability to use knowledge to solve problems or to adapt to new situations.

intelligence, artificial (AI) **1.** An interdisciplinary approach to understanding human intelligence that uses the computer as its experimental vehicle. The many disciplines that contribute to the field of AI include computer science, engineering, business, psychology, mathematics, physics, and philosophy. See **design. 2.** Using symbolic pattern-matching methods to describe objects, events, or processes and to make inferences. **3.** The aspect of computer science that is concerned with building computer systems that emulate what is commonly associated with human intelligence. See **intelligence, artificial; machine, ultraintelligent.**

intelligence, emotional (EI) The emotional, personal, social, and survival dimensions of intelligence. These aspects of intelligence are often more important than the cognitive aspects of general intelligence.

intelligence, human See **computerized knowledge-based engineering.**

intelligence, natural Intelligence derived from networks, rather than artificial intelligence.

intelligent database A database that deals with knowledge as well as data. See **computer database.**

intelligent device See **device, smart.**

intelligent plastic See **plastic, smart.**

intelligent processing See **processing, intelligent.**

intelligent, robot See **robot, intelligent.**

intelligent sensor See **sensor, intelligent.**

intensifier See **pressure booster.**

interface **1.** The boundary between the individual, physically distinguishable constituents of a material, such as between filler and plastic. Also called *interfacial.* See **tension, interfacial 2.** The means of information interchange. See **communication protocol. 3.** The boundary between two systems across which information is transmitted that includes a human working with a computer. See **computers.**

interference fit See **fit, interference.**

interlaminar condition See **reinforced plastic, interlaminar.**

interlaminar shear See **shear, interlaminar.**

interlock See **design, snap-fit; safety interlock.**

intermolecular bonding See **molecular bonding.**

internal bubble cooler See **extruder-blown film internal bubble cooler.**

internal mixer See **mixer, internal.**

International Electrotechnical Commission See **electronic standard, international.**

International Organization for Standardization See **ISO; medical packaging; SI.**

Internet See **website.**

interpenetrating network (IPN) A branch of blend technology that combines two plastics into a stable interpenetrating network. Many types of blends, such as synergistic types, meet various performance requirements. In true IPNs, each polymer is cross-linked to itself but not to the other, and two polymer networks interpenetrate each other; these become thermoset plastics. In semi-IPNs, only one polymer is cross-linked; the other is linear and by itself would be a thermoplastic; these lend themselves to TP processing techniques. The rigidity of IPN structures increases mechanical and other properties such as chemical resistance. A polyurethane and isocyanate system is an example of a full IPN. Polymerizing an elastomeric like polysulfone within a cross-linked TS epoxy can make a semi-IPN.

The simplest method of preparing IPNs is sequential preparation. A cross-linked polymer is produced and then put into a second monomer with cross-linking agent and cross-linked polymerized. The result is a suspension-type plastic and a true IPN. Another method of preparing true IPNs is simultaneous synthesis. Here the two components are polymerized more or less simultaneously but by different routes. An example is by addition polymerization for one and condensation polymerization for the other to avoid interference. Many variations are used, such as for latex IPNs. An IPN may have a core shell structure, with two different networks on the same latex particle, or two latex materials may be bonded together, with two cross-linked networks. All these processing actions result in new engineering-type plastics that have special high-performance properties. See **alloy/blend; blending; chemistry; copolymer; material, microphase structure; polyphosphazene plastic.**

interphase The boundary region between a bulk plastic and an adherend in which the plastic has a high degree of orientation to the adherend on a molecular basis. It plays a major role in the load-transfer process, such as between the reinforcing fiber and plastic matrix and between the bulk of an adhesive and its adherend. See **adherend; reinforced plastic.**

interrelation, business See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

interrelation plastic, process, product See **plastic, processing.**

in-train See **train.**

intrinsically conductive plastic See **plastic, electrically conductive.**

intrinsic viscosity See **viscosity, intrinsic.**

introfaction See **impregnation, introfaction.**

intrusion molding See **injection molding, intrusion.**

intumescent coating See **coating, intumescent.**

invention See **legal matter: invention.**

inventor See **capital and inventors; legal matter: concoct.**

inventory A list or catalogue of all supplies (equipment, materials, controls, etc.) that is done on a time schedule. See **A-B-C analysis; just-in-time;material handling; production data acquisition; production order point; storage; warehousing.**

invest early Development often can be speeded up by making bigger investments, of both people and money, at the front end of the project. Benefits include better product definition, a concept that is better suited to market conditions and availability, fewer dead ends, and better contingency planning. Top management should participate heavily in the early deliberations. See **business bookkeeping; capital-equipment investment; research and development; sales investment turn.**

investment capital See **capital-equipment investment.**

investment casting See **casting, investment.**

in vitro Medical or scientific term that means "in glass" and refers to existence outside a living body and in an artificial environment such as in a laboratory test tube.

in vivo Medical or scientific term that means "in the living body" and refers to existence in a living body.

I/O device Input/output equipment that is used to communicate with a system. See **motion-control system type.**

iodine treatment See **adhesive, iodine treatment.**

iodine value See **test, iodine value.**

ion An atom or group of atoms that carries a positive or negative electric charge as a result of having lost or gained one or more electrons. It becomes a free electron particle. Ions may be positively charged (cations) or negatively charged (anions). See **atom; complex agent; complex ion; energy lattice; plastic, ion-exchange; plastic solvation; solution volumetric analysis.**

ion-beam polymerization See **polymerization, ion-beam.**

ion-beam surface modification A process that uses a highly reproducible ion beam to make changes to the surface of materials. The surface can become biomaterial silicone elastomer hydrophilic, antithrombogenic, or wettable by ink. This occurs without changing the material's bulk properties. Thus, application of low-friction plastic may not require fluorosilicone oil. The process also provides a smooth rather than a wrinkled surface morphology, facilitating resistance to cells especially platelets. See **hydrophilic surface; surface treatment.**

ion, carbanion A negatively charged organic ion compound.

ion, carbonium A positively charged organic ion compound.

ion cationic reagent See **cationic reagent.**

ion chromatography See **chromatography, ion.**

ion-dipole force The force between an ion and a molecule that has permanent dipole moments.

ion effect, common The shift in equilibrium caused by the addition of a compound having an ion in common with the dissolved substance.

ion, electrovalent bond See **atom electrovalent bond.**

ion exchange, plastic See **plastic, ion-exchange.**
ionic Relating to or characterized by ions.
ionic bonding A moderate form of cross-linking that contributes strength and adhesion to thermoplastics. See **cross-linking.**
ionic compound A substance that contains cations and anions. Examples include NaCl, LiF, and MgO.
ionic equation, net A chemical equation in which only those species that actually take part in the reaction are shown. See **chemical-reaction equation.**
ionic initiator Either a carbonium ion (cationic) or a carbanion (anionic) that attacks the reactive double bond of vinyl monomers and adds on, regenerating the ion species on the propagating chain.
ionic polymerization See **polymerization, ionic.**
ionization A chemical change by which ions are formed from a neutral molecule of an inorganic solid, liquid, or gas. See **acid ionization constant; electroplating; rad; radiation dosimeter, solid-phase chemical; sterilization, gas plasma.**
ionization foaming See **foamed polyethylene ionization.**
ionization polymerization See **polymerization, ionization.**
ionization process See **electrical corona resistance.**
ionization radiation Any electromagnetic or particulate radiation that in its passage through matter is capable of producing ions directly or indirectly. See **radiation-induced reaction.**
ionization radiation dose See **radiation dose.**
ionization x-ray method See **x-ray ionization method.**
ion, macro- See **molecular, macro-.**
ionomer plastic A thermoplastic that exhibits very strong interchain ionic force and contains pendant ionized acid groups that create ionic cross-links between chains. Usually, only <10% repeating units of ionomers contain ionized groups, whereas polyelectrolytes contain substantially more. A typical commercial representation of this group is ethylene mythacrylic acid copolymer sodium salt. Its major component is ethylene. The ionomers offer high flexural and impact toughness in the temperature range from −100 to +82°C (−150 to +180°F). They have excellent resistance to puncture and to organic solvents, mild acids and bases, and edible oils; high adhesion to paper and other substrates; and good dielectric properties. Many ionomers are FDA approved for food packaging. They are used in packaging, shoe soles, auto bumper guards, laminated bags, sporting goods, and foam sheets.
iridescence The loss of brilliance in metallized plastics and the development of multicolor reflectance. It is caused by the cold flow in plastic moldings and coatings and by excess heat during vacuum metallizing. See **metallizing, vacuum; plating, silver-spray.**
iridescent metallic luster See **bronzing.**
iron A large family of iron alloys, usually called *steels*, that are the most common of the commercial metals. Iron ore constitutes about 5wt% of the earth's crust and is easy to convert into useful forms. It is a versatile material. The carbon content markedly affects iron's microstructure and hence its properties. Iron melts at 1,525°C (2,777°F) and boils at 2,450°C (4,442°F). See **die material; electromagnetic interference; ferromagnetic material; iron; metal; metal, ferrous; mold material; ore; recycling steel with vinyl scrap; steel resources, limited; waste; zinc.**
iron alloy A steel that possesses special properties that result from the inclusion of other elements, such as nickel chromes. Such materials are used in the manufacture of machines and molds. See **injection molding, nonplastic; photoetching tool.**
iron, cast The generic name for a group of metals that basically are alloys of carbon and silicon with iron. Relative to steel, they are high in carbon (0.5 to 4.2wt%) and silicon (0.2 to 3.5wt%). They are used in all types of plastic processing equipment since they make excellent casting alloys.
iron corrosion See **corrosion resistance.**
iron, gray A supersaturated solution of carbon in an iron matrix that produces a ductile iron with improved stiffness, strength, shock resistance, and wear resistance.
iron impregnation See **metal impregnation.**
iron ingot Highly refined steel with a maximum of 0.15wt% impurity. Due to its high purity, it has excellent ductility and resistance to rusting and corrosion. See **furnace, blast.**
iron modulus versus specific gravity See **modulus versus specific gravity.**
iron, neodymium boron See **plastic, magnetic.**
iron ore depletion See **steel resources, limited.**
iron oxide pigment An inorganic pigment that is produced synthetically or occurs naturally, whose colors may be yellow, red, brown, maroon, or black. The pigments are dull and tinctorially very weak. Heat stability and light fastness are excellent in most systems. See **colorant.**
iron-plastic impregnated See **impregnation.**
iron plating See **chrome plating.**
iron, stainless steel Stainless steel is an iron-chromium alloy that contains a minimum of 10.5wt% chromium (chrome). These steels have exceptional properties that range from heat resistance to corrosion resistance.
irradiation Exposure to radiation; bombardment with a variety of subatomic particles, usually alpha-, beta-, or gamma-rays. It is used to initiate the polymerization and copolymerization of plastics and in some materials to change their physical properties. See **radiation; sterilization, radiation.**
iso- **1.** A prefix that denotes the presence of a branched carbon chain in a molecule. **2.** A prefix that denotes equality or the same numerical value.
ISO The International Organization for Standardization was founded in 1946 and is headquartered in Geneva, Switzerland. Its mission is to promote the development of international standards and the activities that demonstrate

compliance with the standards. See **American Standards for Testing; medical packaging; sterilization, radiation. Appendix C, Worldwide Plastics Industry Associations.**

ISO-2859 sampling See **sampling acceptable quality level.**

ISO-9000 certification ISO-9000 and ISO-9004 are guidelines that interpret the requirements of the three main standards—ISO-9001 (the quality system in design and development), ISO-9002 (the quality system for quality assurance in production and installation), and ISO-9003 (the quality system for quality assurance in final inspection and testing). These three standards define the quality-system requirements for firms with a varying scope of business requirements. See **design verification; fabricating, world-class; processor certification; productivity; quality system; test certification; testing and quality control; transducer calibration.**

ISO-9004 certification See **ISO-9000 certification; quality management, total.**

ISO-10993 certification A practical guide to designing subchronic and chronic systemic toxicity tests. This ISO cites ASTM document F 1439–92, entitled Performance of Life-Time Bioassay for Tumorigenic Potential of Implanted Materials. Material biocompatibility testing occupies a central position in safety-assessment programs for various products. Through the use of such tests, fabricators are able to select materials and manufacturing processes that contribute to the creation of products that are safe for people to use. See **biocompatibility; hemocompatibility; safety; test, carcinogenicity; test, medical-device compatibility.**

ISO-14000 certification The first international standard for environmental-quality management. It is not a compliance standard but consists of voluntary guidelines for constructing a management system from start to finish to ensure that objectives for environmental compliance are set and met. Plant certification will provide evidence of proactive environmental management and will reduce their exposure to lawsuits and regulatory problems. See **plastics cradle-to-grave.**

ISO TC-209 certification An ISO technical committee that was established in 1993 to develop an international standard for cleanroom and associated controlled environments. Thirty-four countries are active with a target to have the standard issued by year 2000. See **cleanroom standard; quality-system regulation.**

isobar absorption See **absorption, isobar.**

isochronous See **creep isometric and isochronous graph.**

isocyanate A highly reactive monomer that contains the isocyanate radical -NCO. See **diisocyanate; foamed polyurethane; reaction-injection molding.**

isocyanate allophanate A reactive polymer of an isocyanate and the hydrogen atoms of a polyurethane. See **foamed, polyurethane; polyurethane plastic; reaction-injection molding.**

isocyanate plastic A material that is based on the condensation of organic isocyanates with other compounds. It generally reacts with polyols on a polyester or polyether backbone molecule, with the reactants being joined by the formation of urethane linkage. See **polyurethane plastic.**

isomer See **atom, isomer.**

isometric See **creep isometric and isochronous graph.**

isotactic plastic A plastic molecular structure that contains a sequence of regularly spaced asymmetric atoms that are arranged in like configuration in a polymer chain (head-to-tail, etc.). Isotactic plastics are crystallizable. See **atom; chemistry, stereo-; molding, isotactic; molecular structure, isotactic; stereospecific plastic.**

isotherm A section at constant temperature through a phase diagram. See **energy, van Hoff isotherm; temperature.**

isothermal **1.** Relating to or marked by changes of volume or pressure under conditions of constant temperature. **2.** Relating to or marked by constant or equality of temperature. See **extruder, isothermal. 3.** See **flow model.**

isotope Two or more atoms of a chemical element with the same atomic number and position in the periodic table and nearly identically chemical behavior but with different atomic mass and different physical properties. See **atom; periodic table; radioisotope.**

isotropic See **birefringence; directional property, isotropic.**

isotropic, optically See **birefringence.**

IV measurement See **viscosity, intrinsic.**

Izod impact test See **test, Izod impact.**

J

jacket A hollow cover for mixing vessels, barrels, platens, and molds that is used to hold circulating water or steam for heating or cooling the particular equipment.

Japanese workmanship Before 1950, Japanese workmanship was synonymous with inferior quality, but current Japanese precision and workmanship produce top-quality products that have changed world markets. This turnabout was fueled by workers' dedication to improving the nation's economy and to their adoption of quality-control methods, such as those taught to top management and engineers by W. Edwards Deming. Referred to as the American who remade "made in Japan." Well before 1940, Deming had established a reputation for himself in the United States as a statistician. Following professional duties in India, he accepted General D. MacArthur's 1946 request to assist Japanese statisticians in their reconstruction by applying his knowledge to their manufacturing plants. He predicted that Japan would invade worldwide markets with quality products within five years; they made it in four years. Because of his work in improving quality, the Union of Japanese Science and Engineering (JUSE) instituted the annual Deming Prize. Later his work was accepted in the United States. See **risk, acceptable.**

jar mill See **mill, jar.**

jet See **fiber processing, jet-spinning; injection molding, jet; injection molding, jetting; splay mark; welding, jig.**

jewelry, core-molding See **soluble-core molding.**

jig A device that is used to hold or align component parts in place and guide the tool during machining or assembly operations. Also called *fixture*. See **machining jig; welding, jig.**

job shop See **processor, custom.**

joining The joining of a plastic part to another part that is composed of the same or a different plastic material, as well as other materials, such as metal. It is often necessary when (1) the finished assembly is too complex or large to fabricate in one piece or (2) disassembly and reassembly is necessary, for cost reduction or when different materials must be used within the finished assembly. Also called *joint*. See **adhesive; adhesive, solvent; adhesive starved joint; assembly/joining; bond strength; cold heading; debond; design; sealant joint-shape; design, snap-fit; fastener; fastener, mechanical; fit, interference; injection molding, in-mold; insert; insert molding; insert, threaded mechanical; knot; molecule, bifunctional; nail; printed circuit board; shear joint; staking; subassembly; welding.**

joining, adhesion See **adhesion, mechanical.**

joining-and-bonding method A joining technique that may involve adhesives, dielectrics, hot gas, hot plates, induction, heat-shrinkable products, mechanical fasteners, solvents, spin, and ultrasonics. See **adhesive; design disassembly; fit; molding two-shell; orientation and heat-shrinkability; welding.**

joining, ball-and-socket See **injection molding, two-shot.**

joining bond breaker A release material that is placed in a joint to prevent the undesired adhesion of a sealant to the substrate or the back-up material.

joining, butt Joining two parts at right angles to each other. See **welding, fusion.**

joining, butt-fusion A method of joining thermoplastic pipe or sheet in which the ends of the two pieces to be joined are heated (usually hot plate) to the molten state and then rapidly pressed together, followed by cooling.

joining, conjugate Two sets of faulty joints that formed under the same stress conditions, such as shear loading. See **shear; stress.**

joining, design The shaping of mating parts to achieve the intended assembly results. See **design assembly.**

joining, edge Bonding the ends of two materials.

joining efficiency A numerical value that is expressed as the ratio of the strength of the joint to the strength of the bulk material. See **material, bulk; strength.**

joining, fillet A rounded filling that fills the corner or angle where two materials are joined. See **fillet.**

joining geometry Several types of mechanical joints are successfully used, particularly with reinforced plastics. Single shear joints (straight lap, offset lap, butt, tapered butt, etc.) and double shear joints (butt, straight, tapered, etc.) each meet different load, space, and other requirements. For example, with double-shear butt joints, the bending stresses common to the other joints are avoided, while the tapered butt joint minimizes excessive loads at the joint edges.

joining, lap A joint in which one adherend is placed partly over the other adherend; overlapping areas are bonded together. See **filament winding lap.**

joining, rivet An assembly process in which a short rod with a head on one side is inserted into a preformed hole in two or more parts. The straight end of a metal rod is then pressed or hammered to form another head and join the parts. With plastic rivet rods, heat and pressure are used to form the head. See **staking.**

joining, scarf Joining that is made by cutting away similar angular segments on two adherends and bonding the adherends with the cut areas fitted together.

joining, sealant See **caulking compound; design, sealant joint-shape; sealant.**

joining, self-tapping screw A method of mechanically fastening two or more plastic parts together in which a screw is inserted in a pilot hole to form mating threads in the plastic part. Self-tapping screws can be either thread-forming or thread-cutting.

joining, thread-cutting screw A type of self-tapping screw that has a sharp cutting edge. Thread-cutting screws remove plastic chips as the screw is inserted or rotated so that the internal stresses that are produced are low. Usually, only minimum reassemblies are possible.

joining, wet-installation A bolted joint in which a sealant is applied to the head and shank of the fastener such that after assembly a seal is provided between the fastener and the elements being joined. See **fastener; strength, wet.**

joint-Y See **filament-winding knuckle area.**

joule A unit of energy in the SI system that is equal to the work done when the point of application of a force of one Newton (N) is displaced through a distance of one meter (m) in the direction of the force. The heat dimension of joule is $N\ m$. Also called J (joule). See **energy; test, impact; torque.**

just-in-time (JIT) A method of keeping processors and customers with a minimum of inventory to reduce their individual costs. This procedure requires precision-timing schedules for all concerned. See **fabricating process; material handling; production-control system.**

jute See **fiber, jute.**

K

kaolin A fine inert white or gray pigment that is used as filler. Also called *china clay.* See **china clay.**
Kapton DuPont's trade name for its family of polyimide plastic films.
Kelvin Scale A temperature scale that uses Centigrade degrees but makes the zero degrees signify absolute zero—$-273.16°C$ ($-459.69°F$). Thus, $K = °C + 273.16$. See **temperature; temperature, absolute zero.**
keratin A filler that is based on calcined feathers, hog bristles, and the like. It is sometimes used in place of wood flour. See **filler.**
kerf The width of a cut made by a water jet, laser beam, torch, or saw blade. It is the material lost. See **cut, kerf, and registration.**
ketchup bottle The popular biaxial stretched squeezable coextruded recyclable blow-molded bottle that uses PP/EVOH barrier/PP plastics with adhesive interlayers followed by PET/EVOH/PET/EVOH/PET, and other combinations. It was introduced by Heinz Co. in 1983. See **barrier plastic; blow molding, stretched; coextrusion; plastic material type.**
ketone A solvent that is characterized by one or more carbonyl groups within a hydrocarbon structure. Examples include acetone and methyl ethyl ketone. They possess a high solvent power for certain plastics (such as vinyl) and many substances that are soluble with difficulty in other groups of solvents. Also called *acetone.* See **acetone; chemical reaction, Zimmermann.**
ketone plastic This broad family of crystalline plastics includes polyetherketone (PEK), polyetheretherketone (PEEK), and others (PEKK, PEKEKK, etc.) See **crystalline plastic.**
kettle A container in which a plastic is produced, separated, or compounded or mixed.
Kevlar DuPont's trade name for its organic polymer that is composed of aromatic polyamides (aramids) having a para-type stretched orientation (parallel chain with bonds extending from each aromatic nucleus). These fibers have extremely high tensile strength and greater resistance to elongation than steel. It is used in fibers and films. Aramid fibers in reinforced plastics provide light weight with high strength and modulus. See **fiber, nylon.**
K-factor See **coefficient of thermal conductivity.**
kieselguhr See **diatomaceous earth.**
kinematic viscosity See **viscosity, kinematic.**
kinetic A branch of dynamics that is concerned with the relations between the movement of bodies and the forces acting on them. See **Avogadro's law; reactor technology; thermogravimetric analysis; viscoelasticity, linear; viscoelasticity, nonlinear.**
kinetic coefficient of friction See **coefficient of friction, kinetic.**
kinetic energy dissipated Plastics provide various degrees and excellencies for producing parts that absorb and dissipate energy, usually from impact. See **energy absorption.**
kinetic friction Friction that develops between two bodies in motion. See **friction.**
kinetic theory A theory of matter that is based on the mathematical description of the relationship between pressures, volumes, and temperatures of gases (PVT phenomena). This relationship is summarized in Boyle's law, Charle's law, and Avogadro's law. See **Avogadro's law; Boltzmann, Ludwig; gas pressure and temperature.**
kink **1.** A type of a waviness that occurs as interior edges, not to be confused with the more abrupt departures as ridges or surface marks. See **tubing; waviness.** **2.** In fabric, a short length of yarn that has spontaneously doubled back on itself to form a loop. Also called *curl yarn, looped yarn,* or *snarl.* See **fiber processing; yarn twist, balanced.**
kirksite A popular alloy of aluminum and zinc that is used to make prototype molds or short production runs. It is an easily melting alloy with a high degree of heat conductivity which makes it easy to produce a mold. Pouring temperatures are as low as 800°F as compared to 3,000°F for steel and 2,000°F for beryllium-copper castings. See **conduction heat; die material; mold material.**
kiss An abbreviation for "Keep it simple and safe," "Keep it simple, stupid," and "Keep it short and simple."
kiss roll coating See **extruder roll coating, kiss.**
Kling test See **test, Kling fusion.**
kneading The elements that are used for melting, mixing, dispersing, and homogenizing. The kneading compounding elements are comprised of individual kneading discs of various widths, which are offset from each other. The kneading discs can be staggered for forward conveying, reverse conveying, or zero conveying; many have one, two, or three lobes. Selecting a disc width, offset angle, number of kneading discs, and direction of conveying controls the level of shear input and the type of mixing action. Various other types of screw geometries utilize interrupted or cut-screw flights. The working principle is the same as for kneading elements; conveying efficiency is reduced to the benefit of back flow for mixing. The degree to which the screw flight is interrupted directly influences the degree of mixing. See **calendering material; compounding; mixing.**
knife See **coating, knife; extruder-sheet air knife; granulator knife; spin trimming.**

knit line 1. See **weld line.** 2. A potential defect in reinforced plastics (SMC, etc.) where plastic flows together but fibers fail to bridge the gap. Knit lines are formed when two flow fronts meet, usually at the extremity of a mold cavity. See **reinforced plastic.**

knitting See **fabric, knitted.**

knockout pin See **mold ejector.**

Knoop hardness See **test, Knoop hardness.**

knot 1. An imperfection or nonhomogeneity in materials that are used in fabric construction, the presence of which causes surface defects. 2. See **yarn, knot tenacity.** 3. A joining by tying substances together. See **joining.** 4. In wood, the portion of a branch that has become incorporated in the body of a tree that is either attractive when used as a decorative pattern or a potential weak section when used in construction. See **wood.**

knowledge See **computerized knowledge-based engineering; plastic product failure.**

knuckle area See **filament-winding knuckle area.**

kraft paper Paper that is made from sulfate wood pulp. It is used in the manufacture of certain industrial and decorative laminated plastics. It provides good mechanical and electrical properties. See **fourdrinier; paper.**

krypton (Kr) A colorless, odorless, relatively inert gaseous element that is found in air. It is one of the noble gases, so-called because their activity is extraordinarily limited. It is in fluorescent lamps and in a flash lamp that is employed in high-speed photography. See **fluorescent; noble gas core; periodic table.**

K showcase See **shows and conferences.**

Kubelka-Munk theory See **computer color matching, Kubelka-Munk theory.**

Kunststoffe The German word for *plastic.*

L

label A precut, printed, flexible material that is affixed to the surface of a product or printed directly on the product and that can be applied during fabrication of the product. See **decal; decorating; laser marking; printing, screen.**

label, adhesive-bonded A label that uses an adhesive that is applied during labeling or that is preapplied. Wet and hot-melt adhesives are used. Preapplied adhesives are mainly pressure sensitive. Adhesives are identified as permanent, removable, and low-temperature operations. See **adhesive, pressure-sensitive.**

label, heat-transfer A label that requires a temperature at or above 100°C (212°F) for the bond to occur. See **bonding.**

label lug See **bottle lug.**

label, pressure-sensitive A label that requires slight applied pressure for bonding to occur.

labor See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

laboratory accreditation Formal recognition that a testing laboratory is certified to carry out specific tests. See **bottle standard marine reference material; computer-aided laboratory; ISO-9000 certification; test laboratories, worldwide approval of.**

laboratory atmosphere, standard An atmosphere that has a relative humidity of 50 ± 2% at a temperature of 23 ± 1°C (73.4 ± 1.8°F). See **atmosphere.**

lac A resinous substance that is secreted by a scale insect and used principally in shellac. See **shellac.**

lacquer A suspension of natural or synthetic plastics, such as nitrocellulose plastic, in readily evaporating solvents. It is used as a protective coating. See **copal; dichloroethylene; solvent-borne coating.**

lacquer coating A formulation that is based on thermoplastic film-forming material that has been dissolved in an organic solvent. The coating dries primarily by evaporation of the solvent. Lacquers are used with vinyls, cellulose derivatives, and acrylics. See **coating, cellulose lacquer.**

lacquer primer See **primer.**

lactam A cyclic amide that is produced from amino acids by the removal of a molecule of water.

lag molding See **molding, lagging.**

lamella (pl. lamellae) A thin, flat scale of a liquid or part. See **antifoaming agent; spectroscopy, Raman.**

lamellar thickness A characteristic morphological parameter that is usually estimated by x-ray studies or electron microscope. The thickness is usually 100 to 500 A (10 to 50 mm). It is the average thickness of a lamella in a specimen.

lamina (pl. laminae) A single ply or layer in a laminate or reinforced plastic that is made up of a series of layers. See **laminate; reinforced plastic.**

laminar flow See **coolant, laminar flow; melt flow, laminar; Reynold's number.**

laminar, inter- See **reinforced plastic, interlaminar.**

laminate An industrial or decorative product that is made by bonding or fabricating together two or more layers of materials. It includes papers, nonwoven (mat) fabrics, and woven fabrics that are impregnated or coated with plastic. It may have a surface material, such as aluminum foil or decorative sheet. It also applies to reinforced plastics and composites of plastic films or sheets without or with foils. Different techniques are used for fabrication, such as pressing, molding, bonding, spread or extrusion coatings, coextruding, coinjection, and processes used for reinforced plastics. Different shapes include flat sheets, rods, and tubes. Fabrication techniques include heat and pressure as well as no heat and very little pressure. Laminates started to be produced during the 1920s using layers of paper or fabric (pulp, cotton fiber, etc.) with thermoset plastics (later thermoplastics) and were used in markets such as decorative panelings, room partitions, and electrical printed circuit boards. By the late 1930s and early 1940s, the term *reinforced plastic* began to include laminates and later the term *composite* became fashionable. See **adhesive contact angle; adhesive, disbonded; caul plate; clamping pressure; coextrusion; coinjection molding; composite; debulking; directional property; directional property, biaxial; directional property, coordinated; directional property, parallel; directional property, symmetrical; extruder coating and lamination; fiber, laminated; foam inverse lamination; hybrid; joining lap; molding, laminated; molding pressure; molding pressure, contact; molding pressure, high; monolayer; plywood; postforming; press, block; pressure; reinforced plastic; reinforced plastic, interlaminar; reinforced plastic let-go; reinforced-plastic nesting; reinforced plastic peel ply; reinforced plastic, premolded; reinforced plastic prepreg; safety glass; sheet overlay; stamping, reinforced thermoplastic; starved area; test, laminated curved-bar delamination analysis; test, nondestructive acoustic emission; test, nondestructive impact RP coin tapping; tie layer; veneer; wood veneer; zero bleed.**

laminate bending Bending a laminate by applying a load with heat. See **laminate, high-pressure formable.**

laminate, copper-clad A laminated plastic that is surfaced with copper foil and widely used in the production of printed circuit boards for the electronic industry. See **printed circuit board.**

laminate, cross See **directional property, crosswise.**

laminate, de- Failure between layers in a laminate structure failure that is caused by the poor bonding of adhesive on plastic. See **adhesive, disbonded; test, laminated curved-bar delamination analysis; test, nondestructive ultrasonic.**

laminate, decorative A surfacing sheet (paper, plastic, aluminum foil, etc.) that incorporates different design patterns with different colors and that becomes an integral part of the thermoplastic or thermoset plastic laminate. Aluminum foil can be a second layer providing the capability of dispersing heat. Cigarette-proof grades previously used aluminum foil (with TS plastic), and later the foil was eliminated after production runs accidentally did not include the foil and the product was still cigarette-proof. See **aluminum foil; decorative sheet.**

laminate, high-pressure formable High-pressure laminates include the postforming grades. These laminates retain a degree of thermoplasticity that enables them to be bent or otherwise formed. The heat and pressure employed in this operation also completes the cure. See **laminate bending; postforming.**

laminate, low-pressure Both thermoplastic and thermoset plastics are used in the lay-ups. See **molding pressure, low.**

laminate ply One layer of a laminate product that is bonded to adjacent layers in the curing process.

laminate, pressure break A break in one or more of the outer sheets of fabric, paper, or other base that is visible through the surface layer.

laminate, sheet A sheet or board of laminated plastics.

laminate stacking sequence A description that details the orientations of the plies and their sequence in the laminate. See **directional property.**

laminate tube or rod Laminated material, prior to heat and pressure curing, that is rolled either on a mandrel or on itself. See **mandrel.**

laminate wood A high-pressure bonded-wood product that is composed of layers of wood with plastic as the laminating agent. Plywood is a typical example. See **wood compressed; wood, ply-.**

laminate wormhole Elongated air entrapment in the surface of a laminate.

lamp black A black or gray substance that is made by burning low-grade heavy oils or similar carbonaceous materials with sufficient air and in an enclosed system. It is used as a filler and pigment. See **filler; material, powder; pigment.**

land A component surface in the manufacturing processes that influences melt flow. See **die land; mold, flash; mold land; screw flight land.**

landfill and degradation Making products that are degradable may not alleviate the solid waste problem. Paper, grass clippings, and food wastes have been found in a state of mummification after 25 to 50 years of burial. A better approach is to minimize waste at its source, recycle what is technically and economically feasible, and convert waste to energy through the incineration of combustibles that cannot be or are not feasible to be recycled. See **bacteria; biodegradable; biodegradable waste; biodegradable versus photodegradable; degradable; energy reclamation; environment; geomembrane; geotextile.**

landfill denked paper See **paper, denked.**

landfill protection See **geotextile.**

landfill, recycled Landfill that is stabilized using the usually nondegradable landfills. Many studies on landfills reveal that very little degrades quickly. Landfills safely entomb waste so that uncontrolled degradation does not endanger groundwater and that the capped (usually with polyethylene plastic sheets to not let water penetrate the waste) land can be used for parks, golf courses, airports, and so on. See **incineration; polyethylene plastic; recycle.**

lap See **filament winding lap; joining, lap.**

lapping See **finishing, ashing and lapping.**

laser A device that is used to produce an intense light beam with a narrow bandwidth. The term *laser* is an acronym for "light amplification by stimulated emission of radiation." See **kerf; magnetic-optical technology; sensor, laser; welding, laser-beam.**

laser marking With the right equipment, most thermoplastics can be marked by a laser. The advantages of the laser-marking clean process include rapid production speed of up to 7,000 mm/s (273 in./s) or 200 characters/s, excellent print quality, no surface contact required allowing marking of flat to difficult-to-reach areas, good wear resistance (10 to 200 μm depth), high information density (line widths under 100 μm and character heights under 1 mm), zero adhesion problems, quick changes, and short set-up times. It has low operating costs with ease of integration; its rather high initial purchase cost is offset by high productivity. It competes with pad printing and hot stamping. It uses either photomasking or beam-diversion processes. Its limitations include limited multicolored markings and unsuitability for large area surfaces. See **barcode; packaging.**

laser sintering, selective (SLS) Certain production tooling (dies, molds) and products can be made from SLS and provide rapid tooling time. The approach used is to prepare a CAD/CAM three-dimensional solid model and download it into a rapid manufacturing computer software system that builds the prototype model. From start to finish SLS takes less than one-half of the time it would take to cut a solid steel or other material. SLS can use a variety of metal-sintering powdered materials as well as a laser-sinter matrix of powdered metal with a plastic binder. The powdered metals in place of photopolymers are used in modeling stereolithography. SLS can build up parts from laser-cured photopolymer (such as PC, nylon, ABS/styrene acrylonitrile, and investment casting wax). With additive-layer, sinter cast steel, it can become harder than its machined counterpart. With a laser-sintered matrix of powdered metal in a plastic binder, once removed from the SLS platform, the part goes through an oven to burn away the plastic. If required, a second oven cycle then clears the way for copper or other materials to be wicked or drawn into the voids left by the plastic. Some of them are machineable and usually strong enough to be used for limited functional testing. See **modeling; photopolymer; prototype, rapid.**

latent heat See **heat, latent.**

latex (pl. latices, latexes) An aqueous dispersion of natural or synthetic elastomeric rubbers and plastics. They are dispersions of plastic particles in water. The most important of the plastic latexes are copolymers of styrene and butadiene, homopolymers and copolymers of vinyl acetate, acrylates, and vinyl chlorides, as well as polyvinyl chlorides and other specialties. They provide water-based compositions (paints, binders, etc.), high pigment-binding capacity, uniform quality as compared to natural binders, relatively low cost versus binding efficiency, good adhesion to substrates, and ease of clean-up. The major use for plastic latex is in adhesives, coatings, paper binders, and textile bondings. Also called *emulsion*. See **colloidal; elastomer; emulsion; emulsifying agent; hydrosol; rubber, natural; sludge.**

latex, agglomerate See **rubber latex, agglomerate.**

latex coagulant See **zinc nitrate.**

latex, creamed A latex concentration that has been increased by creaming and removal of the separate serum.

latex, elastomer See **acrylic emulsion; elastomer.**

latex emulsifying agent A surface-active substance that is used to facilitate the dispersion of an immiscible liquid compounding material in another liquid and to stabilize the mixture. See **emulsifying agent.**

latex foam A cellular plastic that is made from latex. See **foam.**

latex gel A semisolid system that consists of a network of aggregates in which a liquid is held. See **gel.**

latex gel time The period of time from the initial mixing of the reactants of an elastomeric composition to the time when gelation occurs as defined by a specific test.

latex, interpenetrating network See **interpenetrating network.**

latex, mechanical stability The ability of latex to resist coagulation under the influence of mechanical agitation.

latex mold See **mold, flexible.**

latex, natural rubber (NR) Most NR latex is coagulated by the addition of acetic or formic acid to produce natural rubber that is subjected to centrifugation or creaming. The stability of concentrated latex is preserved by the addition of about 1wt% ammonia. See **coagulation; electrophoresis; masticate; peptizer; polyisoprene rubber/plastic; rubber, natural.**

latex precoagulum Coagulum that results from the partial inadvertent coagulation of a latex. See **coagulation.**

latex, rubber or plastic A colloidal aqueous dispersion of rubber or plastic. See **electrophoresis.**

latex serum The dispersion medium of a latex.

latex sludge An undesirable residue in a latex.

lattice The structural arrangement of substances such as plastic properties or atoms in a crystal. See **filament-winding lattice pattern.**

laundry soap See **alkylate sulfonate, linear.**

law See **legal matter.**

law of conservation of matter See **conservation of matter, law of.**

lay-flat film See **extruder-blown film lay-flat.**

layout, plant See **design, plant layout via computer.**

layup See **laminate; reinforced-plastic layup.**

L/D ratio See **screw length-to-diameter ratio.**

leach To extract a soluble component from a mixture by the process of percolation. See **percolation.**

leachate A contaminated liquid that drains from landfills and must be treated before entering the environment. It can contain decomposed wastes, decomposition by-products, heavy metals, or bacteria. See **geomembrane.**

lead **1.** The distance in an axial direction from the center of an element such as a screw flight at its outside diameter to the center of the same flight. See **directional property. 2.** A heavy metal, Pb is hazardous to one's health if inhaled or swallowed. Its use is restricted. In plastics it is found in certain products, such as additives. Pb can be used in safe environments since it has excellent performance properties, such as resisting attack by many corrosive chemicals and is impervious to x-ray and gamma radiation. See **hazard; x-ray.**

lead-alkali glass See **glass composition.**

lead chrome An inorganic pigment that provides a range of yellow, orange, and green colors for plastics. Lead chromes tend to darken on exposure to daylight and, being based on lead, may be attached by sulfur when exposed to industrial atmosphere.

leadership See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

leakage, container See **container leakage.**

leakage detection See **container leakage.**

lease or buy See **capital-equipment investment.**

leather-dust An organic, noncellulose filler.

leatherlike material See **molding, flow; photo-etching tool; poromeric plastic.**

legal matter See **risk, acceptable.**

legal matter: accident reporting Fabricators and manufacturers do not plan for their products to fail or to cause harm to people. Serious accidents must be investigated immediately to prevent them from reoccurring. U.S. federal regulations require that a manufacturer report them to the Consumer Product Safety Commission (CPSC). The customer, the patient, his or her family, and the manufacturer also need to know what happened. Manufacturers should have a trained crisis-management committee in place before a complaint is received so that standard operating procedures define what actions are to be taken and by whom. See **safety.**

legal matter: acknowledgment The document that accepts a customer order, includes a delivery promise, states the method and time for payment, and identifies any exceptions to the terms and conditions stated on the customer's purchase order. See **legal matter: product liability law.**

legal matter: agreement not to compete The consent of the seller of a business not to be in competition with the buyer. See **business.**

legal matter: biomaterial liability bill The Biomaterials Access Assurance Act of 1998 exempts suppliers of raw materials for implantable medical devices such as heart valves and artificial hips, so long as the material is not at fault and the supplier had no role in the design of the device. The purpose of the act is to maintain a supply of biomaterials to the device manufacturers. See **biomaterial; design, biomedical-product; medical market.**

legal matter: bottle bill A law that requires a returnable deposit on certain containers (carbonated beverage bottles, etc.) and a redemption system to discourage reckless disposal of containers and encourage recycling. Also called *deposit law*. See **bottle.**

legal matter: Consumer Product Safety Act (CPSA) A significant consumer safety law. It augments the common law on product liability. The purpose of the law is (1) to protect the public against unreasonable risks of injury associated with consumer products, (2) to assist consumers in evaluating the comparative safety of consumer products, (3) to develop uniform safety standards for consumer products and to minimize conflicting state and local regulations, and (4) to promote research and investigation into the causes and prevention of product-related deaths, illnesses, and injuries. Its goal is to prevent hazardous materials and products or defectively designed products from reaching the consumer. See **risk, acceptable.**

legal matter: contract See **legal matter: product liability law.**

legal matter: copyright The ownership of a design or literary property that is granted by law. See **design protection; legal matter: trademark.**

legal matter: defendant While anyone along the trail of commerce (manufacturer, wholesaler, or retailer) can become a defendant in a lawsuit, the manufacturer usually is held liable by the injured party because the manufacturer is the one from which the largest award can be obtained. See **legal matter: Consumer Product Safety Act; legal matter: product liability law; risk, acceptable.**

legal matter: design protection See **design protection; risk, acceptable.**

legal matter: employee assignment of an invention In assigning an invention, the employment contract usually governs. In states that have employee invention laws, however, employees retain personal, nonbusiness-related inventions as long as they are not made on the employer's equipment or time. See **legal matter: patent.**

legal matter: environment See **ISO-14000 certification.**

legal matter: ethic See **ethics.**

legal matter: expert witness Litigation in the plastics industries usually involves patent infringement, theft of trade secrets, product liability, or specific performance. Prior art and knowledge of the requirements for patentability will often be key parts of the patent expert's testimony. The job of the expert is to reduce a complex art or science into easy-to-understand testimony.

legal matter: fair market value (FMV) The price that a product brings when it is offered for sale by one who is willing but not obligated to sell and is bought by one who is willing or desires to buy but is not compelled to do so. See **legal matter: free trade.**

legal matter: forensic science and plastic A hybrid applied science that embraces any of the natural, engineering, or medical sciences and that may be called on for assistance in the administration of criminal or civil justice. It involves trace evidence, failure, and flammability results, with all kinds of materials and products (plastics, metals, etc.).

legal matter: free trade The debates over free trade versus managed trade or protectionism basically are academic. The United States, which has been the world's leading proponent for free trade, has experienced net international trade deficits for many decades. The U.S. plastics industry has been successful in its international trade business.

legal matter: Insurance Risk Retention Act (IRRA) This act allows companies in the same industry to form a specialized insurance company to insure themselves. For example, one was established in Vermont in 1992 that is called the Plastics Industry Risk Retention Group (PIRRG). See **risk, acceptable; risk management; risk retention.**

legal matter: invention The chief requirements for an invention are that (1) it be unobvious to a person having ordinary skill in the art to which the claim pertains and (2) knowing everything that has gone wrong before is not applicable. See **legal matter: patentability; capital and inventors.**

legal matter: legislation See **World of Plastics Reviews: Challenge 2000—Making Plastics a Preferred Material.**

legal matter: mold contractional obligation Custom molders have traditionally assumed no responsibility for the legality of the design of the customer's product, the design of the molded part as a component of that product, or parts produced to the customer's design and specification. In the event a molded part infringes, or is claimed to infringe, any letters of patents or copyright, the customer assumes the responsibility involved. Most quotation forms include clauses that explicitly detail the indemnification provisions and mold storage responsibility. See **mold.**

legal matter: patent In the United States a patent is awarded to the person who first produces an invention and not necessarily to the person who first applies for a patent. The opposite policy prevails in the rest of the world. U.S. policy probably will change to achieve harmony with worldwide patent laws. U.S. utility patents (machines, equipment, etc.) are good for at least 17 years. See **light microscopy.**

legal matter: patentability The following qualifications apply to U.S. patents on an invention or process (1) the invention must not have been published in any country or in public use in the United States for more than one year to date of filing application, (2) it must not have been known in the United States before that date of invention by the applicant, (3) it must not be obvious to an expert in the art or technology, (4) it must be useful for a purpose not immoral and not injurious to the public welfare, and (5) it must fall within five statutory classes on which only patents may be granted—namely, (a) composition of material, (b) process of manufacture or treatment, (c) machine, (d) design, and (e) plants that reproduce asexually.

legal matter: patent information Patents tend to be the literature of technology with full disclosure of invention details. This legal document confers to its owner the right to exclude others from using it.

legal matter: patent infringement Ignorance of the patent or trademark rights of others is no excuse for an infringing activity. Moreover, it may give rise to costs and risks in withdrawal or recall of products, ads, and attorney fees. These potential costs probably outweigh the cost of the initial searches or clearances.

legal matter: patent plastic money Australia introduced a PP plastic $5 note in 1991 for its antiforgery capability and followed with other notes. The transition from paper currency was completed in May 1995 with the introduction of the $100 note. A U.S. patent was granted in 1993.

legal matter: patent pooling with competitor In the past, U.S. competing companies could not cooperate, such as in R&D, without breaching antitrust laws. Patent pooling, such as collecting and cross-licensing patents, was precluded. Today the antitrust laws are reviewed, interpreted, and enforced less stringently, which permits industrial cooperation in selected and specific areas where pooling does exist.

legal matter: patent search There are three major steps to a patent search: (1) the U.S. Patent Classification System is a subject index to all patents, (2) CASSIS is a computerized software information system provided by the U.S. Patent Office, and (3) reviewing the patent takes time and involves reading the weekly official worldwide gazette and magazines. There are many ways to search the patent database, both U.S. and worldwide, but one website that is particularly useful to the novice or occasional searcher is one offered by IBM located at http://wwwpatents.ibm.com.

legal matter: patent term extension (PTE) The U.S. PTE Law of 1984 offers an opportunity to extend the effective life of patents for new medical inventions up to five years.

legal matter: patent terminology Preparing a patent and ensuring that proper and protective terms are used requires time and money. Cost per patent has been estimated to be in the millions of dollars.

legal matter: plaintiff A lawsuit is a civil suit seeking compensation, usually monetary, by the plaintiff for damages for some type of liability against the responsible party. A product liability may arise as a result of a defect in design or manufacture, improper service, breach of warranty, or negligence in marketing. Under the doctrine of strict liability the plaintiff must present factual proof of damage. Before the trial the plaintiff is entitled to certain information by right of discovery. It includes all records that pertain to the alleged damage and depositions of individuals involved. Oral depositions before a court reporter permit both sides of the litigation to discover the important facts of the case. See **design packaging; legal matter: product liability law; risk, acceptable.**

legal matter: processor contract A subgroup to the custom processor that has little involvement in the business of the customer and usually just sells machine time. See **processor, custom.**

legal matter: product liability law Two types of law are involved—contract and tort. A contract is an agreement between two or more parties that is enforceable in a court of law. A tort is a civil wrong committed by the invasion of any personal or private right that each person enjoys by virtue of federal and state laws. The personal or private right that is affected must be one that is determined by law rather than by contract. In addition to the tortuous act, there must also be personal injury or property damage. Over half the U.S. states have adopted to varying degrees the doctrine of strict liability tort, which means that the injured person need only prove that a product was unreasonably dangerous to win the case. Various conditions make it easier to win cases. For example, proof that the manufacturer of the product is negligent is no longer required. See **design and product liability; legal matter: acknowledgment; legal matter: Consumer Product Safety Act; legal matter: plaintiff.**

legal matter: quality system regulation See **quality-system regulation.**

legal matter: quotation A document that states the selling price and other sales conditions of a material or product.

legal matter: right to know This law (Fed. Reg. 29 C.F.R. 1910.1200) covers employees' right to know about the chemical hazards to which they are exposed in a working area.

legal matter: risk See **risk, acceptable.**

legal matter: shop right A nonexclusive royalty-fee license that is given to a employer by an employee and allows the employee to use the employer's time or equipment to develop an invention. Shop rights come into play when there is no assignment agreement.

legal matter: software and patent In *Arrhythmia Research Technology v. Corazonix Corp.*, 22 U.S.P.Q.2d 103 (C.A.F.C. March 12, 1992), the Court of Appeals for the U.S. Federal Circuit issued a 1992 decision that could strengthen the legal position that so-called pure software can be patented.

legal matter: tariff A schedule of duties or cost rates that is imposed by a government on imported or exported goods. In certain countries worldwide free-trade agreements exist to offset tariff duties. See **world trade.**

legal matter: term Proper definitions to ensure accuracy of discussions in the plant and in the courtroom. See **defect.**

legal matter: tort liability The tort laws have impeded new biomaterial and medical-device developments by the large companies. It is difficult for them to justify the financial risk incurred from the relatively low level of their sales. Action is being taken to change the laws. See **legal matter: product liability law; risk, acceptable.**

legal matter: trademark (TM) A symbol or insignia that designates one or more proprietary products or the manufacture of such products and has been officially registered and approved by the U.S. Patent and Trademark Office. The acceptable designation is a superscript capital R enclosed in a circle, but quotation marks may be used. There are three levels of TM protection: (1) common law covers unregistered TMs with limited legal protection; (2) state registration of a TM protects the TM in that state only, and (3) federal registration offers registered TM protection across state lines.

legal matter: trade name: (TN) The name or style under which a concern does business. The government may register the TN.

legal matter: warranty Warranties apply to equipment, products, and materials. Fulfillment of warranties tends to be a two-way situation. The warranty relationship can be defined in writing by the warranty document. It goes into detail as to what the original equipment manufacturer seller promises to do in event of equipment failure due to specific causes. It also details the responsibilities of the equipment owner. Sometimes the expectations of the processor and manufacturer are seriously mismatched. The best way to avoid this situation is to clarify understandings before the equipment is delivered. It is usually clear who pays for parts, but responsibilities for shipping, travel, and other costs, can significantly differ from OEM to OEM. See **capital-equipment investment.**

legionnaire's disease See **antimicrobial agent.**

length See **measurement.**

length-to-diameter ratio See **screw length-to-diameter ratio.**

leno weave See **fabric, leno.**

lens, apochromatic A color-corrected lens that focuses on the three colors of blue, green, and yellow in the same plane. See **colorant.**

lens centering The operation on lens elements wherein the element is optically lined up with the axis of rotation and the edges ground concentric with the optical axis. See **optical property.**

lens, color fringe See **chromatic aberration.**

lens, contact Contact lenses are principally used to correct vision deficiencies but also treat certain corneal diseases or change the color or appearance of the eye for cosmetic effect. The first contact lens was fitted during 1888 and made from blown or molded glass. By the 1940s polymethylmethacrylate was being used. The next major development used a hydrogel material based on poly-2-hydroxyethyl-methacrylate in the late 1950s. During the 1960s the first soft contact lens was produced. See **hydrogel; vision correction system.**

lens implant See **medical, lens implant.**

let-down ratio See **concentrate let-down ratio; material-blending let-down ratio.**

lettering, molded See **molded lettering and surface decoration.**

lettering, recessed Depressed letters or designs on a mold-cavity surface. See **mold cavity.**

letterpress plate See **printing, photoengraving.**

level winding See **filament winding, circumferential.**

Lewis acid See **electron, Lewis acid.**

Lewis base See **electron, Lewis base.**

L-glass See **fiberglass type.**

liability See **legal matter.**

licensing patent See **legal matter: patent pooling with competitor.**

life-cycle analysis A study of a material or product from its manufacture and use through disposal. The period can be called *cradle-to-grave.* See **aging; plastics cradle-to-grave; profit and time; time; vinyl composition tile.**

life, half- See **chemical reaction, half-life.**

life of plastic See **plastic, long-life.**

life, pot See **pot life.**

life, shelf See **shelf life.**

life, working See **working life.**

light Radiant energy in a spectral range that is visible to the normal human eye of about 380 to 780 mm (3,800 to 7,800A). The speed of light in a vacuum is 299,792,458 m/s or 1/299,792,458 s. See **electromagnetic spectrum.**

light aberration The apparent change of position of an object that is due to the speed of motion of the observer. Care must be taken not to confuse this effect with that of parallax (mutual inclination of two lines forming an angle) during light experiments. See **aberration; light index of refraction.**

light absorber See **molecule, chromophore.**

light beam image See **test, nondestructive transparent medium light schlieren.**

light, black The light in the near ultraviolet range of wavelengths (3,200 to 4,000 A), just shorter than visible light.

light clarity The clearness or ability to transmit light of a material. See **haze; polarized light.**

light densimeter An instrument that is used to measure the light-transmittal properties of material such as film.

light doppler effect See **electronic doppler effect.**

light-emitting diode (LED) See **metal-to-plastic bond.**

light fastness The satisfactory resistance to light, particularly of the colorants or other additives entering into the composition of a plastic material. Also called *light fastness of color.* See **light resistance.**

light frosting A light-scattering surfacing resembling fine crystal that can occur on plastics. See **bloom; chalking; haze.**

light haze See **light transmission.**

light index of refraction The ratio of the velocity of light in a vacuum to that in a given substance. It is the ratio of the sine of the angle of incidence to the sine of the angle of refraction. Refractive index values for unfilled or reinforced plastics can range from 1.3 to 1.6. Also called *refractive index.* See **birefringence; dimensionless quantity; dispersion; fiber optic; light aberration; light index of refraction; optical property; refractiveness; refractivity; stress, residual; test, nondestructive photoelastic stress analysis.**

light metal See **metal, light.**

light metamerism **1.** The phenomenon that is exhibited by two surfaces that appear to be of the same color when viewed under one light source (daylight) but that do not match in color when viewed under a different light (incandescent lamp). **2.** The appearance of a colored surface changes when the viewing angle is changed. Also called *geometric metamerism.* See **colorant.**

light microscopy A method of viewing an object that utilizes a spectrum of electromagnetic radiations that include the visible spectrum from violet to red, and the invisible ultraviolet and infrared spectra. In the plastics industry, it is used in quality control and problem solving and in investigating compositions, properties, structures, and morphology. In patent applications or litigations, microscopical data are important. In research, data often reveal variations in crystal structure. See **legal matter: patent; quality control; troubleshooting.**

lightness hue See **hue.**

light, photochromic See **photochromic.**

light, polarized See **polarized light.**

light ray The line that is perpendicular to the wave fronts of waves of light that indicates their direction of travel in an isotropic medium. See **directional property, isotropic.**

light reflectance See **coefficient of scatter.**

light refractiveness Light absorption in the surface of a material.

light refractivity The refractive index minus one. Specific refractivity is given by $(n - 1)/d$, where n = refractive index and d = density.

light resistance The ability of a plastic to resist fading after exposure to sunlight or ultraviolet light. See **colorant; light fastness.**

light scattering In a dilute plastic solution, light rays are scattered and diminished in intensity by a number of factors, including fluctuations of molecular orientation of the plastic solute. Observations of the intensity of light scattered at various angles provide the basis for an important method of measuring molecular weights of high polymers. It is also the process by which light or other electromagnetic radiant flux passing through matter is redirected over a range of angles. Significant types of scattering by plastics include scattering of light (both elastic and inelastic plastics), x-rays, neutrons, and electrons. The elastic scattering of light is called Rayleigh scattering and of x-rays is usually referred to as x-ray scattering. See **coefficient of scatter; electromagnetic interference; molecule root-mean-square end-to-end distance; spectroscopy, Raman; x-ray diffraction.**

light scattering loss The part of transmitted energy loss that is due to the roughness of a reflecting surface.

light schlieren system An optical system that is used for the visual display of an ultrasonic beam passing through a transparent substance. See **light; ultrasonics.**

light schlieren test See **test, nondestructive transparent medium light schlieren.**

light-sensitive coating See **printing, photomechanical coating.**

light-sensitive plastic See **photopolymer.**

light stabilizer An additive that improves a material's resistance to light damage. See **barium stearate; oxidation degradation, thermal; pigment; ultraviolet absorber.**

light transmission The percentage of incident light that is transmitted by the plastic. This is often time dependent due to the effects of aging and weathering. The reciprocal of light transmission is the haze value, which increases as the percent of transmission decreases. As a general rule, 0% haze relates to complete transparency, up to 30% is translucent, and more than 30% haze is considered opaque. See **light densimeter; optical property; specular transmission; transmittance of light.**

light transmittance, regular The ratio of the light flux that is transmitted without diffusion to the flux incident.

light translucent-to-transparent change See **plastic, light-switchable.**

light, visible See **light.**

light wave See **holography.**

light, white The radiation over a large wavelength frequency range from ultraviolet to infrared. See **holography.**

light, yellow See **blueing agent.**

lignin A natural (thermoplastic) plastic that is found in wood and woody plants. Lignin reacts with certain chemicals and is used as a binder and extender. See **binder.**

lignite A mined coal that is ranked between peat and subbituminous and contains 35wt% water. Plastics (polyesters and polyamides) can be derived from lignite by oxidation with nitric acid followed by extraction of the nitroacid.

lime (CaO) Calcium oxide, a compound that occurs in the form of colorless crystals that are more or less soluble in water and alcohol. It is used to remove traces of water in vinyl plastisols and in the manufacture of calcium carbide and some plastics. See **calcium hydroxide; glass composition; quicklime.**

limestone ($CaCO_2$) A naturally occurring substance that is used in the manufacture of lime and a source for carbon dioxide. See **glass, plate.**

limit See **population confidence limit.**

limitation See **oil resources, limited; plastic myth and fact; steel resources, limited.**

limiting oxygen index (LOI) The concentration of oxygen that is required to maintain burning. It is the basis for evaluating the flammability characteristics of plastics. See **fire retardance; flammability; test, tunnel fire.**

linear expansion See **coefficient of linear thermal expansion; expansion, linear.**

linearity The maximum deviation from a straight line that connects the measurement signal value at zero load with the measurement signal at rated load.

linearization The substitution of a linear function for a nonlinear one that gives approximately the same relationships over a small range.

linear low-density polyethylene See **polyethylene plastic, linear low-density.**

linear thermal expansion See **coefficient of linear thermal expansion; expansion, linear.**

linear variable differential transducer (LVDT) An electronic displacement sensor. It is a transformer with dual secondary windings that are connected in series and wound to produce opposing voltages. See **injection-molding linear velocity-displacement transducer; transducer, magnetostrictive.**

linen Yarn, thread, or fabric that is made from flax fibers.

linseed oil An amber or brown oil that is obtained from flax seed and used in paint and varnish formulations. See **fiber, flax; paint; varnish.**

lint An unintended foreign substance in a plastic or on a surface. See **contamination.**

linter See **fiber, linter.**

liquid, continuous phase See **mixture, continuous-phase.**

liquid crystal, lyotropic A type of liquid crystalline plastic that can be processed only from solution. See **crystalline plastic; solution.**

liquid crystal polymer or plastic (LCP) LCPs are a unique class of thermoplastics that contain primarily benzene rings in a backbone with molecules that are stiff, rod-like structures organized in large parallel arrays. LCPs exhibit a crystalline phase in liquid; melt state is due to the presence of highly ordered molecular fragments. It is melt processable and develops high orientation during molding or extrusion with resultant significant improvements in strength and modulus from low to high temperatures. It is used with or without fiber reinforcements. Also called *liquid crystalline thermoplastic, liquid crystal plastic, liquid crystal polyester*, or *liquid crystalline polymer.* See **plastic, light-switchable; plastic, self-reinforcing; polyester plastic, liquid-crystal; thermoforming, thermotropic liquid crystal in.**

liquids curing medium See **extruder back-pressure-relief port; extruder liquid-curing-medium.**

liquid, elastic A liquid that, unlike a purely viscous liquid, exhibits elastic effects as well as viscous flow. These may be stress-relaxation effects, where the stress does not become instantaneously isotropic or zero as soon as the liquid is held in a fixed shape. They may also be elastic recovery effects, where the shape does not remain constant as soon as the stress is made isotropic or zero. Many plastic fluids (melts and solutions) show such elastic effects. See **directional property, isotropic; elasticity.**

liquid glass See **sodium silicate.**

liquid, immiscible See **emulsifier agent.**

liquid impregnation, trickle See **impregnation, trickle.**

liquid injection molding See **injection molding, liquid.**

liquid oxygen See **polyarylene ether phosphine oxide plastic.**

liquid penetrant A low-viscosity fluid that contains dye and is placed on the surface of a part to penetrate into the surface flaws and cracks. When the surface is washed, the residual penetrants contained in the part reveal the presence of flaws using natural or artificial lighting.

liquid plastic See **plastic, liquid.**

liquid sublimation See **sublimation.**

liquid temperature See **glass-filament liquid temperature.**

liquid vapor See **distillation.**

liquifier A material, such as urea and ammonium thiocyanate, that is used to reduce the gel point and viscosity of carbohydrate or proteinaceous systems.

liter See **volume.**

litharge (PbO) An oxide of lead that is used as an inorganic accelerator and as a vulcanizing agent for neoprene and certain paints.

lithographic resist printing See **printing, lithographic resist.**

litigation See **legal matter.**
litmus A substance that, by its color, indicates the presence or concentration of an acid (red) or alkali (blue).
living hinge See **design hinge, integral.**
living polymer system See **polymer, living system.**
load Mass or force, depending on use. For example, a load that produces a vertically downward force because of gravity acting on a mass may be expressed in mass units. Any other load is expressed in force units. See **force; gravity; mass; weight.**
load amplitude One-half of the algebraic difference between the maximum and minimum loads in the load cycle.
load and temperature See **designing with the pseudoelastic method; temperature.**
load column crush A measure of the resistance of a plastic, such as a container or support column, to deformation under a vertical load, applied along the container's vertical axis.
load, constant A load that is invariable or unchanging.
load cycle The smallest segment of the load-time function that is repeated periodically.
load cycle rate The ratio of cycles endured under load.
load, dead A constant load that is due to the weight of the product, the supporting structure, and so on.
load deformation See **deformation under load.**
load, dynamic An imposed force in motion that may vary in magnitude, sense, and direction. See **dynamic.**
loader See **material handling.**
load, failure See **design-failure theory.**
load, fatigue See **fatigue.**
load, frictional See **lubricity.**
load, impact See **test, impact.**
loading, creep See **creep loading.**
loading edgewise The application of a compression load on the edge of a material. For compression-molded test specimens of square section, the edge is the surface parallel to the direction of motion of the plunger. For injection-molded specimens of square cross-section, this surface is selected arbitrarily. For laminates the edge is the surface perpendicular to the laminae.
loading, intermittent See **creep loading.**
loading, long time See **creep; creep loading.**
loading, short-term Short-term periods are based on conditions or applications of load, such as short-term stress-strain behavior or impact loading. See **production performance; stress-strain.**
loading, top See **container, top-load.**
load, static See **static load.**
load support When a load is applied to a product and it is required to have equilibrium loading, equal force must act in the opposite direction. These forces are the reactions at the supports such as fixed, free, held, guided, or simple support. See **nail.**
load, uniaxial See **directional property, uniaxial load.**
locked-in-stress See **stress, residual.**
lockout equipment/machine See **safety interlock; safety, machine-lockout.**
log See **blender, dough.**
logarithm The exponent that indicates the power to which a number is raised to produce a given number. For example, 1,000 to the base of 10 is 3. This type of mathematics is used extensively in computer software. See **damping, mechanical; mathematics; optical density; strain, logarithm decrement.**
logarithmic viscosity See **viscosity, inherent.**
logic controller See **motion-control system.**
London dispersion force See **molecular force; van der Waals force.**
loom See **fabric woven; fiber mat, needled.**
loss angle See **dielectric-loss angle.**
loss, business See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**
loss modulus See **modulus, loss.**
lost-core process See **soluble-core molding.**
lost-wax process See **soluble-core molding.**
lot See **material lot.**
low-pressure molding and laminating See **molding pressure.**
low-profile plastic See **plastic, low-profile.**
lubricant **1.** An additive to plastics that provides improved internal or external processing and service wear resistance. To be effective, lubricants must be compatible with the plastics in which they are used, must not adversely affect its properties, and must be easily combined. See **plastic processing. 2.** A coating in a mold cavity that prevents the cured molding from sticking to the mold; the plastic may also contain a lubricant to assist or work alone, permitting a part to be removed. See **additive, slip; antimony oxide; barium stearate; butyl diglycol carbonate; butyl stearate; calcium sulfide; carnauba wax; coefficient of friction; design lubricant, reduced-friction; mold lubricant; silicone plastic; slip additive; stearate; wax; zinc stearate.**
lubricant bloom A cloudy effect that is sometimes seen on plastic surfaces due to excess or release of lubricant. See **bloom; blush.**
lubricity The load-bearing characteristics of a plastic under motion. Plastics with good lubricity tend to have a low coefficient of friction with themselves or other materials and do not have a tendency to gall. See **coefficient of friction; load.**
lug See **bottle lug.**
lumber and plastic See **plastic and lumber; wood.**
luminance The luminous intensity of any surface in a given direction per unit of projected area of the surface viewed from that direction. See **electroluminescence; optical brightener agent.**
luminescent pigment A pigment that produces striking effects in the dark. There are two types: one is acti-

vated by ultraviolet radiation and produces very strong and eye-catching effects of luminescence; the other, known as *phosphorescent,* does not require any separate source of radiation. See **calcium sulfide; fluorescence; pigment, luminous; spectroscopy.**

luminous flux The lumen (lm) is the luminous flux emitted in a solid angle of one steradian by a point source having a uniform intensity of one candela (cd sr). The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation. See **candela.**

luminous flux absorptance The ratio of the absorbed radiant or luminous flux to the incident flux.

luminous fractional reflectance The ratio of the luminous flux that is reflected from and to the incident on a specimen for specific solid angles. See **gloss, specular.**

luminous pigment See **pigment, luminous.**

luster The appearance of a surface of a substance in reflected light. Types include metallic, vitreous (glass or quartz), adamantine (like diamond), plastic, or dull (like chalk). See **surface.**

lyophilic Characterizing a mineral that readily goes into colloidal suspension in a liquid. If in water, it is called *hydrophilic.* Examples include gelatin and glue. See **suspension.**

lyophobic A substance that exists in a colloidal state but with a tendency to repel liquids. It lacks affinity for the suspending medium. If the liquid is water, it is called *hydrophobic.* See **oleophilic.**

lyotropic A type of liquid crystalline plastic that can be processed only from solution.

M

Macbeth apparatus A lighting system that is used for checking color. See **color standard; test, organoleptic taste.**
macerate filler A chopped or shredded material, such as a fabric, that is used as a filler for molding compounds to reduce cost. See **filler.**
machinability The degree to which a plastic can be sawn, drilled, or otherwise worked with machine or hand cutting tools. See **machining.**
machine alignment Proper machine installation. The precision alignment that is built into equipment needs to be properly supported on all its mounting points to ensure ground support stability, precise alignment of equipment, uniform support, and effective control of vibration. Installation and alignment require accuracy. Because proper alignment may occur at room temperature and significant movement can occur during heat up or during operation, the causes of movement must be reconciled to prevent excessive wear or even failure of components. With plasticators, the prime objective is to keep the screw and barrel centerlines coincident to meet the production line height requirement. Installation is a multistep procedure that consists of building a foundation, setting and leveling the machine supports, and aligning the machine components to each other. See **calender; injection molding; reaction-injection molding; rotational molding.**
machine control See **process control.**
machine, coordinated-measuring (CMM) A machine that makes multiple measurements on parts with contours and irregular surfaces or shapes in a fraction of the time that is required for conventional manual gauges. It can be used to measure the critical dimensions of a part in a controlled environment, providing x-, y-, and z-axis dimensional data. Usually a computer controls and records the three-dimensional measurements with a probe that can have a contact or noncontact measuring sensor. See **accuracy; deviation, standard measurement; measurement; prototype.**
machine-direction orienter See **orientation, tender frame and roll.**
machine energy See **electric motor, adjustable-speed-drive; energy input, machine; energy loss, machine.**
machine guard See **safety.**
machine hour-rate A rate that is developed for all types of equipment and reported in various plastic publications. See **production-capacity overhead rate.**
machine interlock See **safety interlock.**
machine lockout See **safety, machine-lockout.**
machine operator's sequence See **operation, automatic; operation, manual; operation, semiautomatic.**
machine precision leveling mount An adjustable mount that permits accurate leveling and absorption of any shock. See **machine alignment.**
machine quality Fabrication with closer tolerances than usual and selection for close adherence to specifications and freedom from foreign matter. See **quality control; tolerance.**
machine reach point The point of furthest reach that an operator is expected to be able to touch when standing with any part of the body touching the side members of the machine. See **operator's station.**
machine rebuilding See **manufacturing, remanufacturing/rebuilding; screw rebuilding and repair.**
machinery operation See **fabricating; World of Plastics Reviews: The Plastics Industry; World of Plastics Reviews: Basics and Overviews of Fabricating Processes.**
machine sales See **blow molding market; gross domestic product; injection molding machine sales; market; plastic consumption.**
machinery sales See **plastic industry machine sales; plastic industry size.**
machinery vibration See **damping; damping, dash pot.**
machine, screwless See **extruder, screwless.**
machine startup and shutdown See **fabricating startup and shutdown.**
machine time, sell See **processor, custom-contract.**
machine tool industry The industry's two broad product groups are cutting machines (milling, turning, grinding, etc.) and forming machines (bending, shearing, etc.). See **tooling.**
machine type See **control drive, optimized; fabricating process type; motion-control system.**
machine, ultraintelligent A hypothetical machine that processes superhuman intelligence for which artificial intelligence researchers are striving. Ethical issues include the desirability of such machines and how we would cope with them. See **intelligence, artificial.**
machine, used A preowned used piece of equipment. It provides a fast source for quick delivery as well as excellent working equipment.
machine tie-bar See **injection-molding machine tie bar growth.**
machining Although most plastic parts are fabricated into their final shapes, some parts require machining in supplemental operations (cutting, drilling, etc.). A variety

of machining characteristics have to be met to ensure the machines are properly used. Factors to consider range from heat transfer to the hardness, or brittleness of plastics. Advances in machine tools and controls boost productivity such as in computer numerical control milling and electric discharge machining equipment. Significant technological shifts continually take place in mold-, die-, and other tool-manufacturing processes. See **chemical etching; chemical milling; cutter; die; electro discharge machine, electroerosive cutting and sinking; grinding; grinding, centerless; iron; mold; mold-cavity hobbing; mold-cavity honing; photoetching tool; roll; sanding; saw; surface finish; surface treatment.**

machining and punching An in-line operation that is important in many high-volume production lines. Various types permit punching simple to complex shapes. See **cutter, die; dicer; die-face pelletizer; punch.**

machining, electric-discharge A method of shaping metal by a process of spark erosion.

machining jig A device for holding a part and guiding the tool during machining or assembly operations. For certain operations heating or cooling is included in the jig to prevent parts from changing shapes, reducing cycle time, or providing stress relief. Also called *fixture.*

machining, photochemical (PCM) A method of making products that are difficult to produce any other way because they are too intricate, too thin, or both. PCM provides benefits such as low cost per unit (especially at low production volumes); inexpensive tooling, even though chemical machining adds costs for cleaners, photoresists, and etchings; and quick turnaround time (tools made fast). See **photoetching tool.**

machining safety Any machining process that generates airborne, respirable particles is cause for concern. The Occupational Safety of the Health Administration publishes guidelines for the amount of exposure to respirable particles that workers should not exceed. The list includes many of the allowing elements, such as stainless steel, H13, P20, and other alloying elements (including chromium, vanadium, nickel, copper, molybdenum, and beryllium). To be hazardous, these particles must be smaller than 10 μm and thus not visible to the naked eye. The large, easily visible particles or chips generated in most machining operations do not represent an inhalation hazard. See **additive; asbestos; beryllium copper; fiber; filler; iron; reinforcement; safety.**

macro- A prefix meaning "large" or "long." See **reinforced-plastic macro property; polymer, macro-.**

macromechanic See **reinforced plastic micromechanics.**

macromolecule See **molecule, macro-.**

macroscopy Interpretation that uses only the naked eye or a magnification no greater than 10 times.

Maddock mixing screw See **screw mixing, Maddock.**

magnesium (Mg) The lightest structural metal that is available, not including foamed metals. See **metal, light.**

magnesium carbonate ($MgCO_3$) A light, white powder that consists of a mixture of crystals and amorphous particles. It is used as filler. See **filler.**

magnesium molding See **injection molding, nonplastic; Thixomolding.**

magnet A device that is used to catch metallic contaminants in virgin and particularly recycled plastics prior or during processing. Magnets of different designs are used to nest and fit in different processing equipment (hoppers, blenders, granulators, etc.). See **electrical permeability, magnetic; ferrite; metal detection.**

magnetic field repelled See **molecule, diamagnetic susceptible.**

magnetic induction See **induction, magnetic.**

magnetic-optical technology A transparent thin substrate coating on an optical disk that contains laser-beam information that is nearly birefringence free and permits rewriting on the disc with increased storage capacity and decreased access time. See **birefringence; compact disc.**

magnetic, para- Being attracted by an external magnetic field. A paramagnetic substance contains one or more unpaired electrons.

magnetic plastic See **plastic, magnetic.**

magnetic resonance imaging (MRI) See **digital imaging.**

magnetic screen See **barrel and feed-unit operation protection.**

magnetic water See **water, magnetic.**

magnetized curie point The temperature at which ferromagnetic materials no longer can be magnetized by outside forces.

magnetostrictive transducer See **transducer, magnetostrictive; welding, ultrasonic.**

mahogany See **zorro.**

maintenance Equipment manufacturers provide appropriate equipment maintenance information. All equipment needs a schedule that outlines maintenance needs during operation and also during downtime. Computer maintenance software has been prepared such as the Maintenance Professional for Injection Molding from Spirex Corp. (Youngstown, OH). The program keeps an ongoing spare parts inventory and provides master lists of replacement part numbers with a list of qualified vendors. It tracks, via graphics, significant changes, such as screw wear and maintenance schedules and histories, for each operating machine and piece of auxiliary equipment. See **barrel borescoping; clean-area fabricating; extruder drive maintenance; extruder gear box; fabricating; injection molding machine maintenance; mold maintenance; processing-line downtime; screw rebuilding and repair; serviceability; troubleshooting.**

maintenance, preventive (PM) Proper maintenance allows equipment to perform at its maximum output for the longest time. It is less expensive to maintain equipment than it is to replace it. Periodic checkups, adequate staff for specific tasks, and the machine operator performance requirements all contribute to a long life for equipment. See **troubleshooting by remote control.**

maintenance training See **quality; training.**

maleic anhydride A colorless chemical that is derived from vapor-phase oxidation with atmospheric oxygen and catalyst. It is used in producing polyester and alkyd plastics. See **alkyd plastic; polyester plastic, thermoset.**

male mold See **mold cavity, male.**

malfunction See **plastic product failure.**

malleability Easily flattened or rolled without preheating; plasticity. It is the same as ductility except that it is applied in compression. Malleable materials permit high plastic deformation in compression without fracture. See **ductility.**

management, complete-information See **computer-integrated manufacturing.**

mandrel **1.** A tool that is used to hold or move different devices or products, such as rolls in a film line. See **die-head mandrel. 2.** In blow molding, the part of the mold that forms the inside of the blown part through which air is forced to form the hot parison to the shape of the molds interior. See **blow molding. 3.** The cylindrical part of an extrusion die that forms pipe or tubing. See **extruder pipe and tubing; die-head mandrel. 4.** In filament winding, the form that is usually cylindrical onto which preimpregnated reinforcements are wound. See **filament winding. 5.** A hollow cylinder or solid rod, usually of steel or light metal alloy, around which, during the manufacture of reinforced plastic or laminated tube, prepreg fabric or paper is wound prior to curing.

manifold See **mold manifold.**

man-made fiber See **fiber.**

manual See **operation, manual; quality-control manual.**

manual tapping test See **test, coin impact.**

manufactured cost Various factors influence manufacturing and fabrication costs, such as absorption variance, actual costing, allocation, bill of material, budget, capacity variance, cost of sale, depreciation, direct and indirect charge, expected productivity, volume requirement, labor productivity variance, machine-hour cost, overhead allowed, process cost, raw material inventory, scrap, and tooling cost. See **economic order quantity; fabricating; machining; sales investment turn.**

manufacturing See **computer-aided manufacturing; computer-integrated manufacturing; fabricating employment; fabricating outsourcing; fabricating process; FALLO approach; intelligence, artificial; quality-system regulation.**

manufacturing execution system (MES) A system that focuses on the middle ground between the fabricating or plant floor and the business systems for processing customer orders with product deliveries. They are a critical part of the integrated factory and provide the infrastructure and workflow modeling to link the enterprise's business systems into their existing manufacturing and control systems, gathering process data, directing work in process, and ensuring compliance with established manufacturing practices. Using current and accurate data, MES guides, responds to, and reports on plant activities as they occur. The resultant rapid response to changing conditions, coupled with a focus on reducing nonadded activities, drives effective plant operation and processes.

manufacturing plant, theoretical capacity A plant capacity that assumes that machines are every day run full time at maximum output capacity.

manufacturing, remanufacturing/rebuilding Remanufacturing is a process of engineering a machine and its components to meet or exceed original performance specifications. A rebuilt machine is one that is merely restored to good working order. See **screw rebuilding and repair.**

MAP See **polyolefin plastomer plastic.**

marbleizing See **screw marbleizing.**

Marco process See **reinforced plastic Marco process.**

marine applications for plastics Long-term performance, rather than initial cost, governs most of the selection of a material for marine use in salt and fresh waters. Plastics remain stable for a long time in the severe marine environment, reduce weight and volume, retain their appearance, require little maintenance or lubrication, and resist fresh and sea water corrosion, rot, and fungus growth. Examples of plastics used include polypropylenes, polyamide, and reinforced plastics. Many applications are unique to seagoing vessels on the water surface and underwater as well as on shore. Unless coated, steel and aluminum degrade rapidly in the marine environment. Preservation is essential to maintain function and appearance. The most widely used coatings are epoxy-polyamide plastic systems. See **boat; bottle standard marine reference material; cavitation; coating, antifouling; polyphosphazene plastic.**

market Practically all markets use plastics, including aerospace, agriculture, appliances, automotive, building and construction, cosmetics, dental, drugs, electrical and electronics, furniture, horticulture, industrial, mechanical, medical, packaging, pipe, public transportation, recreation, toys, and so on. See **acrylic plastic; agriculture market; apparel; appliance market; automobile bumper fascia; automotive intake manifold; automotive seat; blow molding market; building and construction market; coating, coil; compact disc; compound; container market; cosmetic market; dental market; electrical-electronic market; energy and bottles; energy efficiency; extruder; extruder industry; film market; foamed plastic market; furniture market; gross domestic product; hydrogel; injection molding machine sales; marine applications**

for plastics; mechanical market; medical market; metal; military market; oil wells, undersea; packaging; packaging, beverage-can; packaging market; packaging, retortable-pouch; pallet; pigment; pipe market; plastic consumption; plastic growth; plastic house; plastic industry size; plastic markets, product and material; printed circuit board cost; reinforced plastic; reinforced plastic process; standard industrial classification; supply chain; toy; transportation market; trucks and plastic; waste and plastic packaging; Figure 7, World Consumption of Plastics by Weight; World of Plastics Reviews: Making Marking Work.

marketing technique See **test, organoleptic taste.**

marking In part assembly, the scuffing or marring of a plastic part, which detracts from its cosmetic appearance. See **cosmetic market; laser marking; splay mark.**

mar resistance The resistance of glossy plastic surfaces to abrasive action. It can be measured by abrading a specimen to a series of degrees and then measuring the gloss of these abraded spots with a glossmeter. Results are compared to a nonabraded area of the specimen. See **abrasion.**

marriage See **plastic marriage.**

mash-off A localized area in a molded panel where the material thickness is reduced from nominal. It usually is used in conjunction with a secondary hole-trimming operation.

mask See **spray-paint coating mask.**

mass A measure of the quantity of matter contained in a body. Units include the gram (g), kilogram (kg), megagram (Mg), and pound (lb). The ton (T) has been given to several large mass units that are widely used in commerce and technology: the long ton is 2,240 lb, the short ton is 2,000 lb, and the metric ton is 1,000 kg. See **gravity; load; matter; measurement; proton; specific gravity; weight.**

mass, atomic See **atomic mass.**

mass density See **density.**

mass saving The reduction of matter and related weight savings, since weight equals mass times gravity, and gravity is assumed to be a constant.

mass spectrometry See **spectrometry, mass.**

masterbatch See **compounds, masterbatch.**

masticate To process an elastomer or rubber to make it softer and more pliable before mixing it with other substances. See **calendering material; elastomer; kneading; latex, natural rubber; mixer; rubber; vulcanization.**

mat Also called *matt* or *matte*. See **fiber mat; preform.**

material A substance. In plastics, the term generally is used in collective expressions such as *raw materials* and *materials handling*. See **additive; compound; concentrate; element; heterogeneous; magnet; pellet; periodic table; plastic failure or success; plastic feed form; plastic material; preform; reinforcement.**

material bailing Compacting material into blocks to reduce the volume and simplify handling and transportation of bulky material. Bales can consist of materials that are unprocessed, recycled, solid waste, and so on.

material bank In equipment such as a mill, calender, or spreader, a reservoir of material at the opening between rolls or at the spreader bar. See **blender; calender; mill; mixer; spreader.**

material, billet A roll of material that can be used in various processes such as pressure forming into rods, bars, and other shapes. See **film, skived; forging.**

material, bio- See **biomaterial.**

material, biscuit A batch of moldings, joined by flash, as produced by multi-impression flash-type molds. See **mold flash; preform.**

material-blending letdown ratio The blending or letdown ratio of a mixture. It is the proportion of one additive or ingredient that is mixed with another, such as the base plastic, to obtain the required compound. A standard method that is used in the PVC industry for providing the correct proportions is in parts-per-hundred (phr) plastic. For example, you could have 26 phr additive and 3.9 phr pigment for 100 parts of plastic. See **blending; compounding; concentrate letdown ratio; mixer; mixing; part per hundred.**

material blocking The undesired adhesion of granular particles. It often occurs with damp powders or plastic pellets in storage bins or during movement through conduits. See **blockage.**

material, briquet A pellet-sized shape that is created by compacting and increasing the bulk density of plastic powders or fine granules, including various additives, by using moderate pressure without heat. Briquets help avoid problems such as dusting, caking, and bridging. Equipment that is used to produce briquets includes using two rotating rolls with half-cavities or pockets cut into their surfaces. Processing heat-sensitive material, the rolls can be water-cooled to counteract heat build-up. Output rates can range from 20 lb/h (0.5 kg/h) for bench-scale models to 100,000 lb/h (45,400 kg/h) with large machines.

material, bulk **1.** The gathering into a large quantity or mass of material. **2.** A situation where a substance is stuffed, swells, or bulges.

material bulk factor See **bulk factor.**

material buy-back An operation where a manufacturer or waste processor buys recyclable plastics from the public. It usually is associated with public collection centers. See **cost.**

material charge The measured amount by weight or volume of material that is used to load a process such as a mold (injection, compression, rotation, casting, etc.) at one time or during each cycle.

material contamination Unwanted different plastics, foreign matter (paper, metal, etc.), angel hairs, fines, fluff metals, and snake skins. The goal is not to produce contaminates in-house or receive them from the material supplier, although equipment is available to remove these contaminates. See **contamination; defect; metal detection; rail car contamination.**

material, cutting burr-free Some products, such as those for electronic devices and medical devices (tubings, inserts, etc.), require an absolutely clean cut without burrs, dust, fluff, streamers, or so-called angel hair. These contaminants can also interfere with conventional fabricating processes so that the material order specifies that none of these contaminants exists. These contaminants tend to exist when plastics are made into pellets or recycled. Lubricating the cutting or granulator knives with water, alcohol, or mineral oil can often help to provide a smooth, clean cut. Also knives coated with PTFE or highly polished chrome are used to reduce friction, resulting in clean cuts. See **cutter; dicer; palletizing; recycling separator.**

material cycle The sequence of extraction, refining, manufacturing, use, and discard or eventual recycle of any materials for use. See **cycle; recycle.**

material distribution The various thicknesses of various parts of a product, such as body, walls, and shoulder.

material doff Removing a finished package (roving ball, twister tube, forming cake, etc.) from a spindle.

material, dry-blend See **compound, dry-blend.**

material, engineering See **design theory and strength of material; engineer.**

material feeding and blending Equipment manufacturers are increasing feeding accuracy by using devices such as microprocessor controllers. Materials are being reduced in size and created with more uniformity to significantly improve uniformity in melt. Processors can use blenders mounted on hoppers that target for precise and even distribution of materials. In volumetric blending, variable-speed metering augers feed multiple components. Operators can calibrate the actual volume by occasionally diverting (manually or with automatic equipment) the mix to a sample chute and weighing the sample. See **barrel and feed-unit operation protection; blender; blending; fabricating output; feeder; material-blending letdown ratio; mixer; plastic feed form.**

material feeding and blending gravimetric Gravimetric blending improves accuracy and process control and requires less operator (if any) involvement in calibration, particularly when running processes where great accuracy is required. Metering by weight eliminates overfeeding of expensive additives. The principle of gravimetric feeding with throughput or metered weight control is well established. Equipment can at least provide an accuracy of at least ±0.25 to 0.50wt% for ingredient and blend ratios of 2σ (two standard deviations). With gravimetric metering, coextruders have a simple means of constantly maintaining the average thickness of individual films and overall thickness at better than ±0.5wt%. By comparison, volumetric and quasi-gravimetric blenders that use a batch operation usually have accuracy variations of 2 to 10wt%. See **feeder, gravity.**

material feeding and blending vibratory See **feeder, vibratory.**

material feeding and blending volumetric Materials are frequently fed in volumetric proportions to one another in many plastic fabricating processes. Several types of feeders are used, including a belt, rotary, slot, vibrator, and single-screw feeder. Since they adjust by volume, plastics are not self-adjusting for any variations in bulk density. See **feeder, volumetric.**

material handling As much as 20 to 40wt% of processing costs can be incurred from handling materials and parts. The design of the raw material system has a major impact on the plant's manufacturing costs and housekeeping. It is based on the different materials used, annual volume of each material, number of different colors, production run lengths, and so on. Different methods are used that range from manual methods to full automation for either raw material or processed parts. Handling is done with automatic bulk systems, in-line granulators, parts removal robots, conveyors, and stackers or orienteers. The equipment chosen must match the productivity requirements. See **auxiliary equipment; barcode; conservation of matter, law of; just-in-time; packaging unitization; part handling; plastic consumption; plastic material; processor certification; rail car, Glasshopper; rail car, SCRIMP; storage; warehousing.**

material handling, automatic Bulk plastic is transported by trucks or rail cars. Trucks typically carry 1,250 ft^3 (35 m^3) of material. Most often the truck has a positive displacement-pumping unit, or the user supplies a pressure system to the silos. Rail cars can store up to 5,200 ft^3 (147 m^3) in four or five compartments with the user providing unloading systems to the silos. Unloading costs are determined largely by the throughput required. Equivalent length is the linear length adjusted for the direction of flow; for example, if the flow is vertical, one unit of length is equal to two units of equivalent length. A continuous vacuum pressure system provides the ability to convey material at the rate required (15,000 to 30,000 lb or 6,804 to 13,608 kg per hour is typical) over almost any distance required (<400 ft or <122 m on the vacuum side, 1,200 ft or 366 m on the pressure side is typical). It is sometimes cost-effective to purchase two lower throughput systems that can unload two cars simultaneously rather than one high-volume single system.

With automatic delivery from silos into the plant, all plastic handling lines are kept as short as possible. There is no reason for lines to conform to the right angles of the walls; they should follow a straight line from the plastic's source to where it has to be delivered. Graphs from handling systems suppliers show the relationship between the length of conveyor lines and power requirements. The graphs also show the horsepower (hp) required, based on different factors, such as the length and diameter of the delivery pipe, the position of the pipe, the type of plastic being conveyed, the size of the hopper at the machine, and the rate of flow deliverable. See **auxiliary equipment; robot.**

material handling baling It is the compacting of material into blocks to reduce their volume and simplify handling and transportation. Bales can consist of unprocessed, recycled, or waste plastics.

material handling, manual Plastics may be supplied in drums holding 15 lb (11 kg) or more; bags holding 50 lb (23 kg); gaylords which are cardboard boxes usually lined with plastic sheets and holding 1,000 lb (454 kg); or bulk fabric sack bags (also called *supersacks, superbags*, or *jumbo bags*) holding 2,000 lb (907 kg), depending on the volume of usage, costs, and moisture situation. Materials are moved from these container systems by vacuum tube conveyors, dumper and pressure unloaders, and fork truck hoists. Plastic storage box containers may be used rather than bags or drums. Box sizes and weights vary and conform to a standard-size pallet on which they are shipped and moved in the plant.

material handling, pneumatic loader and conveyer Bulk material handing and conveying is a combination of theory and experience. Almost any material can be conveyed pneumatically. To date there are no standard, completely integrated formulas for calculating the equipment sizing and the flow characteristics of the material to be conveyed. Most available information on the sizing of a specific material system uses already developed performance graphs that include specific materials (pellet, powder, etc.), conveying distance, location and displacement of the piping system, conveying rate, size of tubings, venturi assist, and pneumatic power requirements. Also important is the experience of the equipment manufacturers who have been developing workable empirical formulas for these graphs. The physics principles that play an important role in pneumatic conveying are gravity, pressure differential (difference to initiate the movement of air and material), inertia (force to overcome the natural resistance to move the material), shear (relative flow between adjacent particles), and elasticity (tendency of a compressed gas to expand and flow from a high to a low pressure). See **conveying, pneumatic; venturi.**

material handling, vacuum loader and conveyor Vacuum conveyors are used for the automatic pneumatic conveying of most free-flowing dry granular plastic materials, such as pellets and powders. With the addition of a low-head separator or a filter-chamber combination, fine powders can also be conveyed with ease.

material handling, vacuum loader, positive displacement Processors who require high-capacity loaders, must convey materials over long distances, or are moving free-flowing powders such as PVC will find that positive-displacement vacuum loaders may best satisfy their needs. A positive-displacement pump supplies vacuum. Such pumps handle up to at least 15,000 lb/h (6,810 kg/h) and distances up to 600 ft (183 m). These larger units are frequently used for bulk railcar unloading to silo storage. These units can also feed several machines through a centralized control system.

material impurity The presence of one or more substances in another, often in such low concentrations that it cannot be measured quantitatively by ordinary analytical methods. See **contamination; material inclusion; purification; scavenger; sensor, inductive and capacitive proximity.**

material inclusion A physical or mechanical discontinuity that occurs within a material or part and usually consists of solid contaminated foreign matter encased in the plastic. See **air entrapment; contamination; material impurity; plastic material.**

material-level sensor Solid and liquid sensors range from simple mechanical devices such as tuning forks to sophisticated devices such as radar trackers. They can track amount, density, and composition changes. See **sensor.**

material lot A specific amount of fabricated products that is produced at one time using one process and constant processing conditions and offered for sale as a unit quantity.

material, microphase structure A plastic system that contains two or more components known as multicomponent plastic materials, alloys, blends, blocks, graft polymers, or interpenetrating networks. They are an important class of materials. See **alloy/blend; compatibility; consolute; copolymer, block; interpenetrating network; miscibility; polymer, graft.**

material, mold See **mold material.**

material optimization See **design, material optimization.**

material phase A structurally distinct part of a material system.

material, powder Any solid, dry material of extremely small particle size that ranges in the colloidal dimensions and is prepared either by comminuting larger units (mechanical grinding), by combustion (carbon black, lamp black, etc.), or by chemical reactions (calcium carbonate, etc.). Powders that are so fine that they cannot be detected by rubbing between thumb and forefinger are called *impalpable*. They are handled in equipment such as bag filters. See **calcium carbonate; carbon black; chemical reaction; colloidal; comminute; grinding; lamp black.**

material, powder compact A molded material that is in the form of dry, friable pellets and is prepared by compacting dry-blend mixtures of plastics, usually PVC, with plasticizers and other ingredients. It offers compounds with low heat history. See **plasticizer; residence time.**

material property, plastic material; recycled material property.

material pulverizing Utilizing a variety of size-reduction or granulating methods to pulverize plastics, including the specialized technique of cryogenic grinding and air-jet milling. Fine, free-flowing powder can be used in processes such as rotational molding and adhesive bonding to improve performance. See **calcining; comminute; communition; cryogenic; granulating; mill; mixing; rotational molding.**

material received, checking An important factor in quality control is that all types of incoming materials (plastics, steel, etc.) conform and are checked against specifications. Specifications may have to be changed to meet unforeseen important tests. See **contamination; inspection; material handling; plastic feed form; quality control; rail-car contamination; rail-track protection; specification; standard.**

material reclamation See **waste.**
material, recovered A material or by-product that has been recovered from solid or other waste but not including those materials and by-products that are generated from and commonly reused within an original manufacturing process. See **inspection; postconsumer; preconsumer; recoverable resource; recycle; waste, industrial.**
material recovery Separating materials from the waste stream for beneficial purposes, such as recycling and incineration to produce energy. See **recyclable.**
material, renewable See **resource, renewable.**
material reprocessed See **plastic, reprocessed.**
material sales See **plastic industry size.**
material, secondary See **recyclable.**
material selection See **plastic material selection.**
material shape See **plastic feed form; plastic material.**
material size See **plastic material.**
material starve feeding A controlled metering device (screw auger, belt, etc.) of material that goes through a feed hopper so that the screw in a plasticator receives less material than what it can handle. Its purpose during certain processing operations is to provide a better or controlled melt. See **venting feeder.**
material supply chain See **supply chain.**
material, strength of See **design theory and strength of material; strengthening plastic mechanism; strength of material.**
material tumbling **1.** Adding and mixing additives (color, etc.) to a dry material through tumble blending. See **coloring, dry; finish; tumbling. 2.** The finishing operation for parts (usually small thermoset plastics parts) by which gates, flash, etc. are removed or the surfaces are polished by rotating them in a barrel or drum together with wooden pegs, sawdust, shells of nuts, small metal spheres, or polishing compounds. See **deflashing; flash; surface finish; surface treatment.**
material type See **plastic material type.**
material variation, reliability factor See **reliability.**
mathematical acoustic impedance A mathematical quantity that is used in the computation of reflection characteristics at boundaries. It is the product of wave velocity and material density. See **test, nondestructive acoustic emission.**
mathematical B-spline A mathematical representation of a smooth curve.
mathematical B-spline surface The mathematical description of a three-dimensional surface that passes through a set of B-splines.
mathematical closure error The algebraic sum of pitch errors of a predetermined number of functional patterns. Also called *runout* or *cumulative pitch error.* See **concentricity.**
mathematical dimension A geometric element in a designed product, such as length or angle, or the magnitude of such a quantity. See **dimensional property.**
mathematical dimensional eccentricity The ratio of the difference between maximum and minimum dimensions on a part, such as wall thickness. It is expressed as a percentage of the maximum.
mathematical derivative The basic mathematical tool for studying rates of change.
mathematical equation A formal statement of the equality or equivalence of mathematical or logical expressions. It is a symbolic expression that represents in an abbreviated form the laboratory observations of a chemical change. See **pi; statistical forecasting.**
mathematical equation, cross- An empirical equation for the shear-rate dependence of the apparent viscosity of a plastic fluid. See **shear rate, melt.**
mathematical model See **calculus; modeling solid; modeling surface; modeling, wire-frame.**
mathematical software See **EnPlot software.**
mathematical theorem **1.** The entities that are deduced from the axioms in predicated calculus. **2.** A statement that can be proved. **3.** The conclusion of a valid argument. See **theory.**
mathematical vector A mathematical term that is completely specified by a magnitude and a direction; a one-dimensional array.
mathematics **1.** An operation or tool with numbers used to answer the questions "how many?" and "how much?" It relates to many functions from material to product evaluations. **2.** A science. In its precision, rigor of development, and search for the truth, mathematics is the ultimate in science—a science of logical reasoning and a study of methods for drawing conclusions from assumed premises. **3.** To the research mathematician, an art with new mathematical concepts being developed daily. More has been developed since 1990 than in all previous time (thanks to the computer). See **algebra; arithmetic; calculus; computer procedure-oriented language; computer science and algebra; decibel; EnPlot software; mean; statistical normal curve.**
mat, needled See **fiber mat, needled.**
matrix See **plastic matrix.**
matter Anything that has mass or occupies space. See **mass.**
Maxwell model A mechanical model for simple linear viscoelastic behavior that consists of a spring of Young's modulus (E) in series with a dashpot of coefficient of viscosity (η). It is an isostress model (with stress δ), the strain (ϵ) being the sum of the individual strains in the spring and dashpot. This leads to a differential representation of linear viscoelasticity as $d\epsilon/dt = (1/E)\, d\delta/dt + (\delta/\eta)$. This model is useful for the representation of stress relaxation and creep with Newtonian flow analysis. Also called *Maxwell fluid model.* See **stress relaxation; viscoelasticity.**
Maxwell-Wagner effect See **dielectric, Maxwell-Wagner effect.**
mayonnaise jar Historically, mayonnaise products have been packed in 16 and 32 oz glass jars. A major evolution is occurring, with PET plastic stretched blow molded

jars providing two times extended shelf life and over 30wt% saving. See **bottle; container; packaging, food.**

McDonald's clamshell bombshell See **environment and public opinion.**

mean The arithmetical average of a set of numbers. It provides a value that lies between a range of values and is determined according to a prescribed law. See **deviation, standard of sample; mean, arithmetic; modulus, mean; servo control-drive reliability; statistical F-test; strain, mean; variance.**

mean absolute deviation (MAD) A statistical measure of the mean (average) difference between a product's forecast and actual usage (demand). The deviations (differences) are included without regard to whether the forecast was higher than actual or lower. See **statistical material selection, reliability of.**

mean and standard deviation The statistical normal curve shows a definite relationship among the mean, the standard deviation, and normal curve. The normal curve is fully defined by the mean, that locates the normal curve, and the standard deviation that describes the shape of the normal curve. A relationship exists between the standard deviation and the area under the curve. See **deviation, standard; statistical normal curve; tensile stress-strain curve; zero defect.**

mean, arithmetic The sum of the values in a distribution divided by the number of values. It is the most common measure of central tendency. The three different techniques commonly used are the raw material or ungrouped, grouped data with a calculator, and grouped data with pencil and paper. More simply called the *mean.* See **arithmetic; computer arithmetic logic unit.**

mean crossing The number of times that the load-time history crosses zero load level with a positive slope, or negative slope, or both, as specified during a given length of the history. See **fatigue.**

mean free path See **molecule mean free path.**

mean limit See **population confidence limit.**

mean square See **variance.**

measure and weight See **decimal number system.**

measurement The six basic units of measurement per SI abbreviations are length in meters (m), time in seconds (s), mass in kilograms (kg), temperature in Kelvin degrees (K), electric current in amperes (A), and luminous intensity in candelas (cd). See **candela; electrical; mass; SI.** Various instruments or devices are used to make measurements during fabrication or after products are produced. See **accuracy; caliper; deviation, standard measurement; injection-molding machine tie-bar measurement; machine, coordinated measuring; micrometer; micron; molded-material surface measurement; nanotechnology; National Institute of Standards and Technology; packaging container content misrepresentation; sensor; transducer.**

mechanical complexity simplified See **servo-control-drive reliability.**

mechanical connector failure See **medical connectors, female luer failure in.**

mechanical, continuum See **Boltzmann superposition principle.**

mechanical control demise See **control drive, optimized.**

mechanical coupling slippage See **extruder-web tension control, slippage and tearing.**

mechanical drawing **1.** The stretching of a plastic material (film, sheet, etc.) by mechanical devices such as molds and plugs. **2.** The stretching of a sheet by differential pressure. See **thermoforming. 3.** The stretching or orienting of a film or sheet. See **orientation, tenter frame and roll. 4.** See **computer graphic; design, graphic.**

mechanical energy; resilience, impact.

mechanical force measurement See **dynamometer, micro-.**

mechanical frequency See **rheological mechanical spectrometer.**

mechanical holding load In mechanical fastening, the load that is required in tensile tests to pull an insert or screw out of the surrounding plastic. See **insert molding.**

mechanical market Plastics continue to be used in mechanical applications in bearings, gears, snap fits, springs, and many other products. They offer simplified designs, long service, reduced maintenance, obviation of lubricants, weight savings, noise reductions, freedom from corrosion, and ease of part identification through use of colors. These advantages have to be weighed against the possible limitations, including those improved by temperatures and type of stress.

mechanical measurement, dynamic gamma loss peak The third peak in the damping curve below the melt, in the order of decreasing temperature or increasing frequency.

mechanical measurement, oscillated See **nonresonant forced and vibration technique.**

mechanical property A property that describes the reaction on a material when different forms of stress and strain are applied; it is the individual relationship between stress and strain. See **chemical property; electrical property; physical property; rheological mechanical spectrometer; testing and classification; test, short-time-behavior.**

mechanical property, superior See **plastic, advanced; reinforced plastic, advanced.**

mechanical property, theoretical versus actual value See **plastics, theoretical versus actual values of; thermodynamics, statistical.**

mechanical, self-lubricating See **lubricant; silicone fluid additive.**

mechanical testing See **test analysis, micromechanical; testing; test, nondestructive.**

mechanic, macro See **reinforced-plastic macro property.**

mechanic, micro See **reinforced-plastic micro property.**

mechatronic Integrating electronics with mechanics. See **electronic.**

medical applications Plastics are used in medical applications that include blood oxygenation, packaging, housing (instruments, disposable, etc.), IV spikes, kidney dialysis, labware, lipid resistant, pregnancy kits, pumps, reusable connectors, snap fits, sterilizable trays, stopcocks, surgical equipment, and syringes. See **hemocompatibility; in vitro; lens, contact; medical absorbable technology; medical suture; prosthesis, quality of life.**

medical absorbable technology A health technique that injects or implants (encapsulated) drugs in absorbable plastic under the skin, thus preventing overmedication and reducing the cost of medical treatment. It provides controlled-release drug-delivery systems. It is involved in bioplastics, biomedicals, drug controlled-release-delivery systems, human implantation, lens implants, microencapsulation, and coatings. See **absorption.**

medical antibody and antigen, plastic-encapsulated When large amounts of homogeneous antibodies are produced to alter normal antibody cells, they are bound to plastic supports and used to purify different molecules. See **encapsulation.**

medical biomaterial See **biomaterial; design, biomedical-product; legal matter: biomaterial liability bill.**

medical building syndrome See **antimicrobial agent.**

medical catheter Catheters are made with extruded tubes of single- and multilumen configurations that meet tight tolerances with important secondary operations, such as insert molding, assembly, catheter printing, and side holes. The balloon angioplastic catheters, which in the past used only latex and PVC for the balloon portion, are also using other plastics such as PET plastic. At least 75% of all catheters are manufactured in the United States with total worldwide sales at $8 billion and growing at least 10% annually. See **design, medical-device; extruder.**

medical chronotherapeutics The timing of medical treatments to take advantage of biological cycles. Medical body-implant formulations are used with a matrix, such as a plastic, to distribute the medication in controlled biological rhythms; release of the drug is controlled rather than by using nonaveraging controlled pills. See **drug, controlled-delivery.**

medical connectors, female luer failure The splitting, leaking, and cracking of the tapered luer connectors that are used to connect IV lines and needles. The female component in particular tended to fail because of stress in the vulnerable hoop direction from the wedging action of the male component. This stress was frequently compounded by the presence of alcohol or fat emulsions, which swelled and softened the material. The male component, subjected only to compressive force, seldom failed since the type of plastic used was designed to take the load. Redesigns of connector materialwise, shape, and processing conditions were made to eliminate the failures per ANSI/HIMA MD 70.1-1983.

medical controlled delivery See **biological activity; drug, controlled-delivery.**

medical cost-of-illness study (COI) An analysis that computes the total costs incurred as a consequence of a specified health-care problem, typically including both direct and the indirect costs such as medical costs and lost productivity. See **fabricating.**

medical-device packaging clarity A major functional requirement of medical device packaging because it makes it easy to identify its contents. Any existing haze flaws from the time of packaging to use become obvious. See **biodegradable waste; coating, microencapsulation; design, biomedical-product; drug application; electronic standard, international; legal matter; biomaterial liability bill; polypropylene plastic; transparent plastic.**

medical-device sterilization See **orientation and heat-shrinkability; sterilization quality assurance; sterilization radiation.**

medical implant See **ISO-10993 standard.**

medical, lens implant An ultraocular lens that is made by various methods, such as sheet casting PMMA and shaping the lenses using a lathe cut and surface modification process. See **acrylic plastic.**

medically sealed See **medical seal and closure; orientation and heat-shrinkability; seal; sterilization.**

medical market A wide range of plastics that are used in the human body and particularly in medical devices and drug packaging. Because of their wide range of properties, ability to be sterilized, and economical benefits, plastics are being used in place of metals and other materials in a number of medical devices. These range from commodity thermoplastics to the most exotic and expensive engineering plastics. The five most commonly used in devices are PE, PP, PVC, PS, and PET. See **biomaterial; commodity plastic; dental market; design, biomedical-product; drug, controlled-delivery; engineering plastic; legal matter: biomaterial liability bill; silicone, medical; skin, synthetic.**

medical material and the environment Reusable medical devices have been replaced by disposables where infectious disease needs to be minimized. Plastics have met performance requirements and are cost-effective for these devices. See **biocompatibility; design, biomedical-product; design, medical-device; electrical power disturbance; environment; packaging, breathable-film; toxicology.**

medical miniaturization See **nanotechnology.**

medical packaging The International Organization of Standardization (ISO) has defined a medical product as the combination of both the medical device and the final package. However, the realities of product development often leave development of the package until long after the product has been fully defined and, perhaps, is in limited production. When a project nears the end of the development period, major changes made to the device itself are difficult and costly, so all aspects of device and package compatibility and packaging performance are achieved exclusively through package-design modifications. When the package design and production are finally undertaken, pressure to market the product soon is high, which can encourage the package-development personnel to make package-design decisions based on intuition rather than on scientific evidence. Even when testing is done, the large number of samples often leads to a product release before tests are completed. See **design packaging; medical seal and closure.**

medical safety reporting See **legal matter: accident reporting.**

medical seal and closure Nearly all pharmaceutical packaging now has tamper-evident seals and enclosures. See **mold, collapsible-core.**

medical standard See **electronic standard, international.**

medical suture Sutures are produced from plastic fibers that can be in different forms such as braided, twisted, or spun. They may be coated with waxes, silicones, fluorocarbons, or other plastics to reduce capillarity and improve handling or functional properties.

megarad See **energy absorption, megarad.**

melamine formaldehyde plastic (MF) A member of the aminoplastics family that is a clear water-white syrup or white powder. Since the 1920s, MF thermoset plastics have been produced in an unlimited range of colors. In the past, prior to the development of our many thermoplastics, MFs were used extensively (electrical, mechanical devices). Their major use is now with alpha cellulose in practically unbreakable dishware that includes design inlays (in-molded) that cannot be washed off, abraded, or damaged. Surface glazing is used to eliminate staining or scratching.

melamine phosphate See **flame retardant.**

meld line A line that is similar to a weld line except the flow fronts move parallel rather than meeting head on. See **weld line.**

melt A charge or quantity of molten plastic. Also called *stock.*

melt analysis See **dielectric analysis.**

melt bambooing See **extruder melt bambooing.**

melt blockage See **extruder melt blockage.**

melt cavity, frozen layer See **mold cavity, frozen-layer.**

melt compressibility See **thermodynamic properties.**

melt cooling rate See **mold cooling rate.**

melt cushion See **cushion; injection-molding melt cushion.**

melt degradation See **screw length-to-diameter ratio.**

melt density The melt density is about 15% lower than the solid density or specific gravity that is listed on material data sheets. It should be determined to obtain a true value. By placing a known weight of material in an enclosed chamber, heating it until it melts (the processing temperature), applying pressure to remove any entrapped voids, and after removing the pressure measuring the melt volume, the melt density can be determined. The known mass (g) divided by the volume of the melt (cm^3) is the specific gravity or density. See **density and specific gravity; thermodynamic properties.**

melt dispersion See **compounding, shear-roll.**

melt, dynamic influence See **damping gamma loss peak.**

melt elasticity As a melt is subjected to a fixed stress or strain, the deformation versus time curve will show an initial rapid deformation followed by a continuous flow. The relative importance of elasticity (deformation) and viscosity (flow) depends on the time scale of the deformation. For a short time elasticity dominates, but over time the flow becomes purely viscous. This behavior influences processes such as when a part is annealed. It will change its shape, or, with postforming (postextrusion), swelling occurs. Deformation contributes significantly to process defects. Melts with only small deformation have proportional stress-strain behavior. As the stress on a melt is increased, the recoverable strain tends to reach a limiting value. It is in this high-stress range, near the elastic limit, that processes operate. Pressure, temperature, and molecular weight has little effect on elasticity. The main controlling factor is molecular weight distribution (MWD). See **elasticity; molecular-weight distribution; strain; stress, elastic limit.**

melt extensibility See **extruder draw-down.**

melt extractor See **injection-molding melt extractor.**

melt filtration See **extruder screen pack; injection-molding screen pack; mesh; particle size; screen pack.**

melt filling hesitation See **mold-filling hesitation.**

melt filling monitoring See **mold-filling monitoring.**

melt flow Measuring melt flow is important for two reasons. First, it provides a means for determining whether a plastic can be formed into a useful product such as a usable extruded extrudate, completely fill a mold cavity, provide mixing action in a screw, or meet product thickness requirements. Second, the flow is an indication of whether its final properties will be consistent with those required by the product. The target is to provide the necessary homogeneous melt during processing that allows the melt to operate completely stable and in equilibrium. In practice, even with past and continuing developments, this perfectly stable situation is never achieved, and a range of variables affect the output. If the process is analyzed, one can decide that two types of variables affect the quality and output rate. They can be identified as (1) the variables of the machine's design and manufacture and (2) the operating or dynamic variables that control how the machine is run. See **blow molding, extruder (continuous-die); butyl stearate; design, basics-of-flow die; die; flow**

model; injection molding melt flow; injection-molding process-control parameter; mold-cavity melt-flow analysis; mold-filling monitoring; molecular weight and melt flow; morphology; plastic solidification; processing, reaction viscosity; product size; rheology; transport property; viscosity, Newtonian flow; viscosity, non-Newtonian flow.

melt-flow analysis Software simulates the desired process and compares it with reality. The purpose of flow analysis is to gain a comprehensive understanding of the melt-flow filling process that is based on process controls. The most sophisticated computer models provide detailed information concerning the influence of filling conditions on the distribution of flow patterns as well as flow vectors, shear stresses, frozen skin, temperatures and pressures, and other variables. Less sophisticated programs that model fewer variables are also available. From these data, conclusions regarding tolerances and part quality in terms of factors such as strength and appearance can be drawn. The location of weld lines and weld-line integrity can be predicted. The likelihood of warping surfaces, blemishes, and strength reductions due to high-shear stress can be anticipated. On this basis, the best filling conditions can be selected. An example of this software is from Spirex Corp. and is called The Molder's Technician. See **polarity; process simulator; training; weld line.**

Computer flow-analysis programs used throughout the plastics industry worldwide utilize two- and three-dimension models in conjunction with rheology equations. Models range from a simple Poiseuille's equation for fluid flow to more complex mathematical models involving differential calculus. These models are only approximations. Their relational techniques, coupled with the user's assumptions, determine whether the findings of the flow analysis have any real validity. What actually happens is determined after processing the plastic. See **flow, Poiseuille.**

When analyzing the results, it is important to determine the type of error. For example, the pressure loss error may be in the thin, thick, or virtually all sections. If the error appears in all, it may mean that there is simply an offset that is caused by a difference between the viscosity data used in the flow analysis and the actual viscosity during processing. If this is true, changing the processing speed should allow the flow-analysis data to be duplicated with a different fill or exit time. If, however, the flow analysis overstated thick sections and understated thin sections, there could be a serious problem with the mathematics used. See **shear stress-strain.**

melt flow, balloon See **mold-cavity melt fountain flow.**

melt-flow Cauchy-Riemann differential equation See **design, melt-flow Cauchy-Riemann differential equation.**

melt flow control See **rheometer, capillary.**

melt-flow defect Flow defects affect the appearance of a product. Typical extruder defects include nonlaminar flow, nonplastication, and volatiles. Sometimes defects are desirable such as in producing a matte finish, sharkskin, and shrinkages. See **design, basics-of-flow die.**

melt flow, fountain See **mold-cavity melt fountain flow.**

melt flow hinder with additive Different additives, such as particulate fillers and especially fibrous reinforcements generally increase viscosity and impede melt flow. See **additive.**

melt-flow index See **test, melt index.**

melt flow, injection molding See **injection-molding melt flow; injection molding melt-shear behavior.**

melt-flow instability See **melt fracture.**

melt flow, laminar It is desirable to have melt that moves in even layers that do not interfere with each other during processing, such as in extrusion and injection molding. This type of flow permits ease of controlling its behavior in fabricating products. See **coolant, laminar-flow; coolant, turbulent-flow; flow, viscous; Reynold's number.**

melt-flow line See **weld line.**

melt-flow model See **flow model.**

melt flow, mold-cavity See **design-mold basics of flow; mold-cavity melt-flow analysis.**

melt flow, nonlaminar When melt does not move in an uneven flow, distortion occurs causing potential problems with fabricated products, such as poor surface finish or not producing similar products. See **melt flow, laminar.**

melt-flow orientation See **blow molding, injection-with-rotation; orientation.**

melt-flow oscillation A process for resolving weld lines during injection molding, blow molding, and extrusion. See **extruder melt-flow oscillation; injection-molding melt-flow oscillation.**

melt-flow property A variety of instruments and procedures are used to measure melt flow and viscosity that basically include rotational and capillary techniques. See **test, melt rheometer; test, spiral.**

melt-flow; melt-flow rate (MFR) An alternate name for melt index. See **test, melt-index.**

melt-flow resistance See **viscosity.**

melt flow, restricted See **injection-molding ultra-high-molecular-weight polyethylene.**

melt-flow stabilizer See **processing stabilizer.**

melt-flow test See **cup-flow; test, melt-flow; test, Brabender plasticorder rheometer melt-flow; test Canadian melt-flow.**

melt flow tracing See **radioisotope.**

melt-flow vibration See **injection molding, vibrational; melt vibration.**

melt-flow volume change See **plastic solidification; thermodynamic properties.**

melt fracture **1.** Instability or an elastic strain in the melt flow usually through a die starting at the entry of the die. It leads to surface irregularities on the finished part like a regular helix or irregularly spaced ripples. Plastic's rheology influences its melt-fracture behavior. Higher-molecular-weight plastics (with MWD) tend to have less sensitivity to its onset. Also called *elastic turbulence.* See **alligatoring; die laddering; extruder-melt bambooing; extruder shark-skin surface; mold-gate blush; molecular-weight distribution; rheology; viscoelastic fluid. 2.** This fracture can also occur in molds with complex cavities or improper melt flow with in the mold. See **molding.**

melt front The exposed surface of a melt as it flows into a mold or through a die. See **mold-filling monitoring; viscometer.**

melt heat transfer See **thermodynamic properties.**

melt index See **test, melt-flow; test, melt-index.**

melting action See **differential scanning calorimetry.**

melting temperature The melt temperature (T_m) at which a plastic liquefies on heating or solidifies on cooling. T_m depends on the processing pressure and time at heat, particularly during a slow temperature change for relatively thick melts. If T_m is too low, the melt's viscosity is high so that more power is required to process the plastic. Degradation can occur if the viscosity is too high. Some plastics have a melting range rather than a single point. Amorphous plastics do not have melting points but rather a softening range and undergo only small volume changes when solidified from a melt or when the solid softens and becomes a fluid. They start melting as soon as the heat cycle begins. It is often taken at the peak of the differential scanning calorimeter thermal-analysis test equipment. Crystalline plastics have considerable order in the molecules in the solid state, indicating that many of the atoms are regularly spaced. They have a true melting point with a latent heat of fusion associated with the melting and freezing process and a relatively large volume change during fabrication at the transition from melt to solid. Also called *melting point.* See **amorphous plastic; crystalline plastic; differential scanning calorimetry; melt temperature; shrinkage; thermodynamic properties.**

melting temperature conductivity See **screw design; screw length-to-diameter ratio.**

melting with screw See **screw, mixing and melting.**

melt instability An instability in the melt flow through a die starting at its land. It leads to the same surface irregularities on the finished part as melt fracture.

melt, non- See **infusible.**

melt plug flow See **design-mold basics of flow; flow, plug.**

melt-pressure decompression The action of reducing melt pressure.

melt-pressure sensitivity The broadening molecular weight distribution of plastics that increases the sensitivity of melt viscosity to changes in pressure. See **molecular-weight distribution.**

melt pump See **gear pump.**

melt rheometer See **test, melt rheometer.**

melt shear rate The speed of a shear-sliding deformation between melt layers of a plastic body per unit thickness of layers along the walls in laminar flow. See **injection-molding melt-shear behavior; pseudoplastic; shear rate, melt.**

melt spinning See **fiber processing, spinning.**

melt stagnation See **adapter system.**

melt strength The strength of the plastic while in the molten state. It is an engineering measure of the extensional viscosity and is defined as the maximum tension that can be applied to the melt without breaking. Linear plastics such as LLDPE, HDPE, and PP generally have poor melt strength because in extension the linear chains slide by without getting entangled. However, branched plastics like LDPE exhibit higher melt strength and elongation viscosity because the long branches get entangled. See **strength; thixotropic; viscosity.**

melt swell See **design-die basic of flow.**

melt temperature 1. The temperature (T_m) at which a plastic melts or softens and begins to have flow tendency. See **injection-molding melt temperature; melting temperature; rubbery plateau; thermal property. 2.** The recommended processing temperature. See **temperature controller. 3.** See **tolerance and shrinkage.**

melt temperature, absolute In a hypothetical characterization, a perfectly free or relative free melt that has consistant temperature, pressure and mixture. See **temperature, homologous.**

melt temperature and color See **color stability and processing.**

melt temperature and glass transition temperature See **glass transition temperature and melting temperature.**

melt-temperature effectiveness Measuring the melt temperature can be deceiving. For example, an extrudate with a room-temperature pyrometer probe often gives a false reading because when the cold probe is inserted, it becomes sheathed with the plastic that has been cooled by the probe. A more effective method uses what some call the 30/30 method. The temperature of the probe is raised about 30°F (15°C) above the melt temperature, and then the probe is kept surrounded with hot melt for 30 seconds. The easiest way to preheat the probe is to place the probe on, near, or in a hole in the die. Preheating above the anticipated temperature, just prior to inserting it into the melt, requires the probe to actually be cooled by the melt. The lowest temperature reached will be the stock temperature. It also helps to move the probe around in the melt to have the probe more quickly reach a state of equilibrium. To be more accurate, repeat the procedure. See **heat-transfer mechanism; temperature sensitivity.**

melt vibration A computerized control system is used to vibrate melt during processing, monitor viscosity, and control microstructure. Vibration is created through hydraulic pumps and servo valves. In a mold, the melt can be oriented in three directions. Results include increases in tensile strength and modulus of elasticity, melt transition temperature, and the elimination of knit line and warping. With extruders, it can reduce barrel friction so that the melt temperature can be reduced at least 20°C. The action permits pelletizing at lower temperature, which allows the use of organic stabilizers and colors that degrade at higher temperatures (patent by Solomat Partners of Stamford, CT). See **injection molding, vibrational; pelletizing.**

membrane A thin barrier nonporous, porous, or semipermeable (permits passage of certain substances and not others) material. The term *permselectivity* was coined to distinguish between a thin, nonpermeable film or layer and a permselective membrane. See **barrier plastic; permeability; water-vapor transmission.**

memory, plastic See **elastic memory; orientation; plastic memory; test, distortion point heat; thermoforming.**

mer See **polymer mer.**

mesh In a screening device, the number of size of openings in a screen per unit area. See **screen.**

mesophase An intermediate phase in the formation of carbon from a pitch precursor. This is a liquid crystal phase in the form of microspheres that on prolonged heating above 400°C (750°F) coalesce, solidify, and form regions of extended order. Heating above 2,000°C (3,630°F) forms graphite structures. See **carbon; graphite; graphitization; fiber, carbon; fiber, graphite; pitch; polyacrylonitrile plastic.**

metal Metals are superior to many plastics in strength and heat resistance, though some plastics can withstand high temperatures for short-term exposures. Most structures and products, however, are not required to withstand high heats and must endure only what the human body can endure. Plastics have lower weight than metals. See **die material; element, strongly positive; ferrite; iron; metal, ferrous; mold material; ore; steel resources, limited.**

metal-adsorption calorimetry A hybrid analytical technique for measuring the chemical bond strength between gas-phase metal atoms and plastics. See **adhesion; bonding; metal-to-plastic bonding.**

metal alloy See **die-casting alloy.**

metal cleaning See **cleaning; coating, fluidized-bed metal stripping.**

metal corrosion protection See **mold storage.**

metal detection Removing metal contamination from virgin plastics and particularly recycled plastics eliminates problems during processing and product use. Metal-detection and -separation technology offers a number of options ranging from simple magnetic removal of ferrous (iron-containing) metals to electrostatic and other techniques that are capable of removing all manner of metals, including copper, aluminum, and stainless steel. The sensitivity of the equipment is measured by the size of the metal particles it can detect. When different types of equipment are combined, the result can be output with metal contamination as low as 5 ppm. Most systems for detecting both ferrous and nonferrous metals are based on the use of conventional or rare earth magnets to create magnetic eddy currents. They are available in different forms. For example, an electrostatic sensor can be placed under the plastics being fed over a conveyor system, and an air jet propels unwanted particles out of the plastic material stream. See **magnet.**

metal, die cast See **plastic and die-cast metal.**

metal, ferrous The large family of iron alloys called steel. See **iron.**

metal fiber See **fiber, metallic.**

metal forming See **injection molding, double-daylight.**

metal fracture Metals fracture basically two ways—brittleness (virtually no plasticity in plastic flow or reduction in a cross-sectional area) and ductility (plastic flow occurs with separation taking place in the direction of the highest resolved sharing stress). See **brittle; design-failure theory, Griffith; fracture.**

metal, heavy An element that has a high atomic weight, such as arsenic, cadmium, chromium, lead, mercury, tin, and zinc. Some additives use these materials.

metal impregnation Though porosity can be found in any type of metal casting or part, it is a particular problem in castings made from aluminum, zinc, bronze, iron, magnesium, and other alloys. Porosity is always present in powdered or sintered metal parts. One of the first materials that was used to fill the porous openings with liquids or gases under pressure was water-glass or sodium silicate. It had limited success. Other materials used included tung oil, linseed oil, and pitch gum, with little success. As of the 1940s, low-viscosity thermoset plastics became very successful and provided an economical sealing method, particularly in conjunction with vacuum pressure. The impregnating material is introduced as a liquid, followed by solidification. There are four common methods of impregnation: dry vacuum pressure, internal pressure, wet vacuum pressure, and wet vacuum alone. The plastics that are used are principally TS polyesters and epoxies with sodium silicate formulation where high temperature is encountered. See **impregnation; porous metal; sodium silicate.**

metal injection molding See **injection molding nonplastic.**

metallic core See **soluble-core molding.**

metallic-organic plastic See **plastic, organometallic.**

metal, light In engineering terminology, a metal that has specific gravity of less than three and is strong enough for construction use (aluminum, magnesium, beryllium, etc.). Most engineering plastics meet this requirement. See **beryllium copper; engineering plastic.**

metallizing plastic Coating plastic products and fibers with metal. Techniques include applying a thin coating of metal by chemical deposition or by exposing the surface to vaporized metal in a vacuum chamber. Also called *plating*. See **coating, sputtered; coating vacuum; electroplating; metallizing, vacuum; plating.**

metallizing, silver spray See **plating, silver-spray.**
metallizing, vacuum A process in which part surfaces are thinly coated with metal by exposure to the vapor metal that has been evaporated under vacuum at about one-millionth of normal atmospheric pressure. See **boat; iridescence; plating; plating, silver-spray; vacuum.**
metallizing, vacuum boat A tungsten container used to hold metal staples during vacuum metallizing.
metallography See **crystallography.**
metal matrix See **composite-metal matrix; injection-molding nonplastic.**
metal molding See **injection molding nonplastic.**
metal molding, matched See **reinforced-plastic molding, match metal.**
metal, non- An element whose electronic structure, bonding characteristics, and physical and chemical properties differ greatly from those of metals, particularly in respect to metal's higher electronegativity as well as thermal and electrical conductivity. See **element, strongly negative; metal detection; optical image spectroscopy.**
metal, nonferrous A metal that is not composed of iron. Examples include aluminum, copper, brass, and bronze.
metal-photoetching tool steel See **photoetching tool.**
metal plating See **chrome plating.**
metal, powdered See **powder metallurgy.**
metal profile plastic coating See **die coating.**
metal-sheathed heater See **thermoforming heater, metal-sheathed.**
metal toner See **pigment, metal-toner.**
metal, tool steel See **photoetching tool.**
metal-to-plastic bond The metal-plastic interfaces are valuable in areas of technology such as microelectronics, molecular electronics, and electromagnetic shielding. For example, novel electrical interconnects can be produced by depositing metal films on insulated plastics and forming multilayer devices. Traditionally, these devices have been made from ceramic insulators. Another area of plastic-metal interface is electronic displays consisting of light-emitting diodes. See **adhesion; bonding; electromagnetic interference; metal-adsorption calorimetry.**
metal vapor synthesis (MVS) The use of atoms of the transition metals as reagents in the preparation of organic, organometallic, catalyst, and other compounds. It provides more direct and higher yield to existing compounds and makes available new compounds.
metal, white A group of alloys that have relatively low melting points, other than copper-based alloys. They usually contain tin, lead, antimony, cadmium, or zinc as the main components. One use is as a soluble core. See **eutectic mixture; soluble-core molding.**
metamerism See **light metamerism.**
metastable Unstable. A plastic may evidence changes in its physical properties that are not caused by changes in composition or environment. For example, some plastics are temporarily more flexible after molding. No physical test should be made while the plastic is in a metastable condition.
meter An SI length unit equal to 100 cm or 39.37 in. See **decimal number system; measurement; number marker, SI.** The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299,792,458 of a second.
metering pump See **gear pump.**
metering system See **mix metering.**
methanalysis process See **recycling, chemical; recycling postconsumer plastic.**
methane See **decomposition, digestion.**
methane diisocyanate See **foamed polyurethane.**
methyl acrylate ethylene plastic See **ethylene methyl acrylate copolymer plastic.**
methyl alcohol An aliphatic alcohol CH_3OH liquid that is colorless, volatile, and flammable. It is derived from the catalytic hydrogenation of carbon monoxide, oxidation of natural gas, or gasification of wood. It is used as a solvent for cellulosic and other plastics, in organic synthesis, for manufacture of formaldehyde, and as a fuel. Also called *menthanol.*
methylcellulose plastic (MC) A water-soluble plastic that is harmless for external body contact or ingestion (edible). It is used in creams or foods as a thickening agent. See **carboxymethylcellulose plastic; plastic, water soluble.**
methyl ethyl ketone peroxide A colorless liquid that is a strong oxidizing agent and irritant to the skin. Its TLV is 0.2 ppm in air (ceiling level). It is a fire hazard when it contacts organic materials. It is used as a hardening agent for glass-fiber-reinforced thermoset polyester plastics and in the manufacture of acrylic plastics. Also called *MEK peroxide* or *ethyl methyl ketone peroxide.* See **exotherm.**
methylfluorosilicone plastic A thermoset elastomer that is designed for demanding service applications such as good resistance to corrosive fluids and other chemicals, as well as to high temperatures. It is used in auto fuel line hoses, gaskets, tubing, and seals.
methylmethacrylate A colorless, volatile liquid that melts at −48.2°C (−54.8°F) and boils at 101°C (214°F). It is soluble in most organic solvents and slightly soluble in water. It is used as a monomer for polymethylacrylate and acrylic plastics.
methylmethacrylate plastic See **acrylic plastic; casting, acrylic-sheet.**
methylphenylsilicone plastic A thermoset that has improved high temperature resistance, oxidation properties, radiation resistance, and compatibility with organic materials. It can be used as a plastic additive or a flow-control agent in polyester coatings.
methylsilicone plastic A thermoset elastomer that is characterized by excellent thermal stability and good resistance to oxidation. It is used in electrical insulation, heat-resistant paints and varnishes, and protective and decorative finishes.
methylvinylfluorosilicone plastic A plastic that, be-

cause of the presence of the vinyl group, may be vulcanized to a high degree of cross-linking. Its use includes applications where high or low temperatures are encountered and where resistance to fuels or oils is required.

M-glass See **fiberglass type.**

mica A group of silicates that are similar in atomic structure but differing in their chemical composition. As fillers they have excellent resistance to heat and good insulating properties and are used in the production of certain plastics.

micelle A colloidal particle that is formed by the reversible aggregation of dissolved molecules. Electrically charged micelles form colloidal electrolytes, such as soaps and detergents that are used in emulsion polymerization. See **polymerization, emulsion.**

micro- See **reinforced plastic micro property.**

microanalysis See **chemistry, analytical.**

microballoon See **microsphere.**

microbe See **biodegrading microorganisms; engineering, genetic.**

microcomputer See **computer architecture; computer-automated laboratory to production; computer, micro-.**

microcrack A minute surface flaw. See **reinforced-plastic microcracking; stress crack.**

microdynamometer See **test, microdynamometer.**

microencapsulation coating See **coating, microencapsulation; drug application; medical-device packaging clarity.**

microfiber See **fiber, micro-.**

microfilm copying See **photopolymer.**

microgel See **gel, micro-.**

microinch See **mike.**

micromechanic See **reinforced plastic micromechanic.**

micrometer A mechanical device for measuring thickness, usually in thousands of inch or mm. See **measurement.**

micromolding See **injection molding, micro-.**

micromorphology See **morphology, micro-.**

micron A unit of measurement. 1 micron = 0.001 mm = 0.00003937 in. = 10^{-6} m, or about 25 microns = 0.001 in. The term micron (μ) is being replaced by micrometer. See **angstrom; measurement; mike; mil.**

microorganism See **biocide; biodegrading microorganisms.**

micropellet See **pellet, micro-.**

microporous See **porous, micro-.**

microprocessor See **processor, micro-.**

microprocessor control A control system that is expected to provide exact acquisition of the significant process parameters, minimum response time, and high reproducibility. Constant maintenance of production documentation is important because of the manufacturer's liability for the product. See **process control; processor, micro-, control.**

microrheology See **rheology, micro-.**

microscope A device that is used to examine the material morphology, molecular orientation, and skin or core structure. See **light microscopy; molecular-level electron microscope; test, microtoming optical analysis; transmission, electron-microscope; x-ray microscopy.**

microscope, polarizing See **polariscope.**

microscopy The use of or investigation with a microscope.

microscopy, light See **light microscopy.**

microsphere A thin-walled hollow sphere that has a diameter in the micron range (20 to 150 μ) and usually is made of plastic or glass. Its wall thickness is 2 to 3 μ. In appearance, bulk microspheres are a free-flowing powder resembling fine sand. Bulk density ranges from 6 to 12 lb/ft^3 (29.5 to 59 kg/m^3). They are used (1) as filler for low-density filled plastics such as syntactic foams, (2) as tiny vinyl spheres to reduce evaporation of liquids such as oils, by floating a layer of spheres on the surface of storage tanks, and (3) as adhesives, usually as a 100 μ diameter sphere that controls bond-line thickness; when the adherends are pressed together the spheres will ensure a bond line thickness such as 100 μ. They are used to impart lightweight and favorable acoustical, thermal, and dielectric properties; to control thermal expansion and adhesive thickness in plastic; and as laser-reflective tracers in aqueous and other liquids, ablative heat shields, radar-absorbent coatings, and prosthetic devices. Also called *microballoons.* See **adhesive; coefficient of linear thermal expansion; filler; glass sphere, solid; plastic material; reinforced-plastic syntactic cellular plastic.**

microstrain See **strain, micro-.**

microstructure See **molecular microstructure.**

microtoming, optical analysis See **test, microtoming optical-analysis.**

microwave See **heating, microwave.**

migration A mass transfer process in which the matter moves from one place to another, usually in a slow and spontaneous fashion. Examples include migration of pigments, fillers, plasticizers, and other ingredients via diffusion, extraction, bleeding, or floating to the surface or through an interface to other materials. Results are defects called *blooming, chalking, bronzing, flooding,* or *bleeding.* See **bleed; bloom; bronzing; chalking; diffusion; electrophoresis; permeability; plasticizer, nonmigratory.**

migration and additives The surface characteristics of a plastic part may be changed by the addition of incompatible additives that migrate to the surface. Additives include fluorocarbons, low-molecular-weight fluoroacrylates, polyamides, waxes, and silica. See **phosphorous-base flame retardant.**

migration and plasticizers Plasticizers may exude from the interior of a thermoplastic product to its surface, where it appears as a greasy or oily film. See **bleed; brittle brashiness; phosphorous-base flame retardant; plas-**

ticizer; plasticizer; nonmigratory; plasticizer, nontoxic.

mike The American Standards Association's term for a microinch or 10^{-6} in.; 1 μm = 39.37 microinch. See **micron; mil.**

mil 1 mil = 0.00254 cm = 0.001 in. or one-thousandth of an inch (0.0001 in.) = 25.4 μm. See **area, circular-mil.**

military market All branches of the military make extensive use of plastics to meet all types of worldwide requirements in water, on land, in the atmosphere, and in outer space. The military continues to be the major source for new plastic material and product developments prior to expansion into major commercial markets. Traditionally, military requirements have strongly influenced the evolution in science and technology throughout the world as developments initiated expansion of new commercial products, such as plastics, computers, electronic devices, and barcodes. Extensive plastics R&D to meet severe military product requirements has occurred since at least the late 1930s. Military aircraft may have up to 80wt% of a primary structure using plastics, principally reinforced plastics. See **aircraft; barcode; calculus; fiber, silicon-carbide; market; missile; research and development.**

milk and plastic See **casein plastic.**

mill A machine for grinding, polishing, size reducing, or uniformly mixing two or more substances, or products. These mechanical and air-jet devices transform raw materials into a condition for use. See **blending; mixer; mixing theory; tumbling.**

mill, attrition A grinding machine that is comprised essentially of two metal plates or disks with small projections (burrs). One plate may be stationary while the other rotates, or both may counterrotate. Feed, such as additives, enters through a hopper above the plates, and ground product emerges at the bottom exit opening. To obtain uniform ground material, different-size vibrating screens are used to separate different existing sizes.

mill, ball A cylindrical or conical shell that rotates about a horizontal axis and is partially filled with a grinding medium, such as natural flint pebbles, ceramic pellets, porcelain pellets, or metallic balls. The material to be ground is added in an amount that just slightly more than fills the voids between the pellets. The shell is rotated at a speed that causes the mill pellets to cascade, thus reducing the particle size by impact. Also called a *pebble mill* when nonmetallic grinding media is used. See **pigment, metallic.**

mill, cage A device that is used to reduce the size of material. Usually two high-speed rotating wheels similar to water wheels are used; one fits inside the other, and in turn the assembly is covered with a close-fitting housing. They have horizontal cross-bars or breaker plates. The plastic that is to be reduced in size is fed into the smaller cage from a hopper. It is ejected at speeds up to 12,000 ft/m (61 m/s) and is fragmented by contact with the bars or plates. As the pieces are thrown back and forth within the cages, they are reduced further by mutual impact.

mill, colloidal A device for preparing emulsions and reducing particle size, consisting of a high-speed motor and a fixed counterrotating element in close proximity to the rotor. The fluid is conveyed continuously from a hopper to the space between the shearing elements and then discharged into a receiver. See **emulsion.**

milled fiber See **fiberglass, milled.**

mill, hammer A crushing or shielding device that consists of four or more rectangular metal hammers or sledges mounted on a rotating shaft with the hammers being free to swing on pins (such as a corn-chucking machine). The rotating hammers impact, crush, and bounce material against a stationary breaker plate. Like a granulator, a porous grid having the desired hole sizes permits material to pass through the holes. This mill is popular with thermoset plastics, particularly B-stage prepregs. See **fiberglass, milled; prepreg.**

milligram molded part See **injection molding, micro-.**

mill, jar A small ball mill. See **mill, ball.**

mill, pug A granulating machine whose essential components are a shaft that is equipped with blades or arms having hardened tips rotating in a troughlike compartment.

mill, rod A closed steel cylinder that is one-third filled with steel rods of about the same length as the cylinder and 1 to 2 in. (2.5 to 5.0 cm) in diameter. As the cylinder rotates, rods roll over one another, exerting a combination of impact and grinding action on the material charge. It results in materials of 50 to 60 mesh screen with a minimum of fines that is used to create plastic fillers and metal powders and reduce the size of ores.

mill, roll A device that is used to prepare compounds. After being processed in a mixer, the compound can be moved on a conveyor belt or dropped directly into the mill for sheeting and dicing or into an extruder or pelletizer. The mill uses two horizontal rolls in close relation to each other, rotating in opposite directions and frequently at different speeds. The milled sheet is then cut into strips or dice cut to provide forms for efficient feeding into fabricating equipment. Also called *two-roll mill.* See **compounding, shear-roll; mixer; pelletizing.**

mill, tube A fine-grinding machine that finish-grinds particulates. It is usually fed 20-mesh material and reduces it to 325-mesh. The mill has a rotating steel chamber that may be from 15 to 50 ft (4½ to 15 m) long and 6 to 8 ft (2 to 2½ m) diameter. Within the chamber are steel balls from 1 to 5 in. (2½ to 13 cm) in diameter. There are batch and continuous types in use. See **particulate filler; screen.**

mineral black See **pigment, mineral-black.**

miniaturization See **electronic microminiaturization; printed circuit board, surface-mounted technology.**

mirror, glass-plated See **plating, silver-spray.**

miscibility Capability of being mixed. See **consolute; material, microphase-structure.**

missile Missiles, rockets, and spacecrafts use different plastics and reinforced plastics to meet all kinds of requirements that range from insulators to structural members. See **military market.**

mix An adequate mixture of a material in any form with other materials. See **blender; feeder; kneading; tumbler.**

mixer A device that is used to blend. The type of mixer selected for a particular job is determined by such factors as material components, form of material involved, agitation desired, and output rate required. A typical use of mixers is to blend powder colorants and plastic pellets, reinforcing fillers and plastics, dry-blending PVC, or powdered plastics with additives. See **blender; blending; blow molding extruder, reinforced-plastic; compound; fluxing; kneading; material-blending letdown ratio; material feeding and blending; mill; mixing theory; screw, mixing and melting; tumbling.**

mixer, ad- The addition and homogeneous dispersion of discrete components prior to processing.

mixer, banbury Equipment for compounding dry materials that is composed of a pair of conterrotating rotors or screws that masticate the mixed materials to form a homogeneous blend. This is an internal mixer that produces excellent mixing action for compounds such as polyvinyl chloride plastics. Both steam and water jacketing are provided. Controlled temperature and pressure exist from the time the material enters until it leaves. See **mixer, internal.**

mixer, batch There are three intensities of batch mixing: low, medium, and high. Low-intensity mixers are the most commonly used because they are the least expensive, are relatively easy to clean, and can be employed for a multitude of tasks where time and dispersion are not of prime consideration. Medium-intensity mixers usually consist of low-intensity mixers fitted with attachments called *intensifiers.* The intensifiers are normally a high-speed mixing head added to the low-intensity mixer. The high-intensity mixer is a high-speed unit with specialized blade designs. Mixing times are typically measured in minutes, as compared to half an hour or more for the other type mixers. High-intensity mixers are used most often in the areas of pigment dispersion and premixing of the compound. See **compound, batch; compound, masterbatch.**

mixer-blender See **tumbling blender-mixer.**

mixer-blender, double-cone A variant on single-cone blender types. It substitutes two cone-shaped cylinders that are joined together by a short cylindrical section. The mixer, which is partially filled with the materials to be mixed, provides a rolling motion, as in a drum tumbler. However, because of the interfolding action of the two cones, this design addresses itself more directly to obtaining better cross-flow in the mixing. It can be fitted with intensifying agitator bars, liquid-spray nozzles, jacketing, and vacuum equipment (for removing volatiles). A prime use is in solid-to-solid mixing, such as with virgin plastics and powdered colorants.

mixer-blender with impeller A machine that incorporates some form of impeller that is generally used to push material mechanically through complicated flow paths. Designs are broad and versatile. Some result in solid-to-solid mixing that can process low-viscosity plastisol and organosol; others can process viscous materials, such as bulk-molding compound.

mixer, centrifugal impact A device that is used for mixing free-flowing dry blends, comprising a conical hopper in which a rotor disk and a peripheral impactor are rotated at high speeds. The plastic is fed into the center of the rotor, which throws it against the impactor blades, which in turn throws the plastic against fixed impactors at the extremities of the cone. From that position, the plastic flows downward to a discharge orifice.

mixer, change-can A planetary-type mixer that is comprised of several paddle blades that are mounted on a vertical shaft rotating in one direction while the can or container rotates in the opposite direction. The paddle is usually mounted on a hinged structure so that it can be swung out of the can, permitting the can to be removed and replaced with ease. This type of mixer is used for relatively small batches of 3 to 125 gallons of fluid dispersions and dry material. Also called *pony mixer.*

mixer, compounder-extruder See **extruder, compound mixing.**

mixer, concentric-screw extruder See **extruder, concentric-screw mixer.**

mixer, cone See **mixer, disc.**

mixer, conical-screw A mixer that uses a screw for conveying and mixing and has a cone-shape mixing chamber. A vertical screw slants up from the base of the chamber to the outside of the top and rotates on its own axis at about 64 rpm while orbiting the periphery of the cone at about 3 rpm. In handling solid-to-solid mixtures, the flow of material is from the bottom to the top. This flow carries mixed material from the walls toward the center of the tank. When handling pastes and viscous liquids (bulk-molding compound, premix, etc.), the screw runs in the reverse direction so that material is pushed down in the base of the mixing chamber, where mixing takes place by a combination of hydraulic and mechanical shear forces. Mixing cycles may be less than 5 minutes, power consumption is low, and the cone design allows for efficient gravity discharge and easy cleaning. Modifications are made to meet different requirements, such as using two screws mounted 180° apart to increase output rate. See **shear force.**

mixer, continuous A mixer that primarily uses extruders. The single-screw extruder is simple in design and reasonably priced and can perform certain desirable functions. It subjects melts to relatively laminar flow. Processing is normally limited to the barrel surface, and conveying is only by drag flow. This action minimizes the use of single screws for low-viscosity mixing. Heat transfer is difficult and is effective only on the barrels. Grooved barrel walls, barrier screws, and shortened screw designs can overcome many of the shortcomings. Important to compounding are the many different multiscrew designs that meet special requirements. These machines provide the capabilities that are required to provide the proper compounding of many different materials. Twin screws provide much higher torque and volume than the single-screw extruders. They are used to give a low melt temperature and very little decomposition of the compound. They often make it easier to process materials with feeding problems.

mixer, disc A continuous mixer that has cone-, flat-, or wedge-shaped discs. It can rotate at speeds of at least 1,200 to 3,600 rpm and displace the fluid that contacts their surfaces by centrifugal force. Series combinations of the disc units increase the machine's mixing or dispersing capability, with parallel combinations increasing output rate. Material, such as paste, that is being compounded can be recirculated for further mixing. See **injection molding nozzle-dispersion disc mixer.**

mixer, disc and agitator A compound mixing device that is comprised of discs or cones rotating at speeds of 1,200 to 3,600 rpm or even higher, which displace fluid contacting their surface by centrifugal force. They are used in preparing pastes and dispersions.

mixer, double-arm A common type of paste-mixer machine. It contains two mixing blades that operate tangentially or overlap in a troughlike mixing chamber. Tangential designs are used when feed materials are in sheets or chunks and resist flowing between blades. Overlapping blades are used for materials that flow more easily. Various types of blades are used. For example, the sigma type is regarded as the general-utility blade; the 180° spiral is for glass-reinforcing materials; the 135° spiral is for larger, overlapping-arm designs; the double-nobbed agitator type is for added shearing actions; and the serrated-agitator type is used when a gripping or tearing action is needed. Because the mixing action of these machines relies primarily on shearing action, mixing is most effective with higher-viscosity compounds. See **extruder paste; mixer, paddle-agitator.**

mixer, extruder Various types of extruders and other machines are used in mixing and compounding plastics, depending on operating cost, maintenance cost, quantity of plastic to be processed, and type of plastic (temperature sensitivity, viscosity, etc.). They range from single to multiple (corotating or counterrotating) screws. Two-stage models (combining twin screws with single screw inline or vertical to each other) incorporate different types of mixing devices and actions to provide the proper melting actions, such as shearing action and residence time required for the different compounds being mixed. See **compounding; extruder, concentric-screw mixer; extruder; mill; residence time; screw mixing.**

mixer, high-intensity A horizontal mixer that has a powerful drive and an infrared temperature sensor that triggers batch discharges. PVC fluxing occurs during high-intensity mixing. See **mixer, medium- and low-intensity.**

mixer, high-intensity nonfluxing A mixer that has a bowl or cylinder with a wall that angles slightly at the top. Instead of the rotors found in fluxing mixers, it has impellers driven by a central drive shaft that enters the mixing chamber at the bottom. Its bottom blades lift material and fling it up on the sides of the mixing bowl. Upper blades (shape of the bowl) direct the material back down to continue the mixing action. The impact action develops heat required to aid in dispersion and in absorption of liquids.

mixer, impingement See **reaction injection molding, impingement mixing.**

mixer, injection molding See **injection molding nozzle-dispersion disc mixer.**

mixer, internal A mixer that uses the principal of cylindrical containers in which the materials are deformed by rotating blades or rotors. The containers and rotors are cored so that they can be heated or cooled to control the temperature of a batch. These mixers are extensively used in compounding all types of materials since they have the inherent advantage of keeping dust and fume hazards to a minimum. Also called *intensive internal fluxing mixer.* See **mixer, banbury.**

mixer, kneader-extruder A variant on the paste double-arm mixer concept. The difference is that in one type of design a screw conveyor is built into the bottom of the mixing chamber. Another uses a rotating reciprocating screw with the barrel having rows of teeth that correspond to wedge-shaped gaps in the screw. During discharge the material is in an easily handleable ropelike form and can then be stored or fed to other processing systems. These mixers are used primarily for highly viscous pastes and have been adapted to mixing materials with viscosities below 1,000 cps. See **kneading.**

mixer let-down ratio See **material-blending let-down ratio.**

mixer, low-intensity liquid For simple jobs like intermittent agitation of materials such as PUR premixes and thermoset polyesters, this type of easily operated equipment is used, but they do not achieve mixes of the same quality as with high-speed mixers. Usually mixing is done in a shipping or holding container. The simply designed impellers use blades shaped like marine or even aircraft propellers; other designs include long slender screws, paddles, and shafts with two or more impellers. These units are intended to generate greater motion within the mixture and greater turbulence at the impeller than the flat blades of the high-speed dispersers, which are intended to go fast enough to shear materials, break down agglomerates, and disperse solids in liquids using less energy.

mixer, low-viscosity Similar to paste mixers, they achieve a uniform dispersion of liquid and solid in a matrix of relatively low-viscosity, as with PVC plastisols and organosols and thermoset polyester gel-coats. As is with paste mixing, however, some of the medium- and low-intensity ribbon-blenders, plow-driven, conical-screw, and other mixers are also suitable for mixing low-viscosity materials.

mixer, medium- and low-intensity Mixers that operate at lower intensities and shear than the high-intensity mixers. The mixing action that is generally involved is distributive in the sense that individual components usually keep their identity and mix with other components in ratios that are maintained uniformly through the entire batch. High-intensity mixers, in contrast, achieve dispersive mixing when the particles of the mix become so intimately blended that there is an actual merging of particle identity. These medium and low intensity machines are generally used for solid to solid blending, blending of solids and small amounts of liquids, and the blending of high-viscosity solids or liquids, although some handle low-viscosity plastisols or organosols, as well as SMC premixes.

mixer, paddle-agitator A simple mixer for plastics in the form of dispersions, pastes, and doughs. The most common form is a set of rotating blades driven by a vertical shaft that intermeshes with a set of fixed blades. See **blender, dough; mixer, double-arm.**

mixer, propeller A device that is comprised of a rotating shaft with propeller blades attached. It is used for mixing relatively low-viscosity dispersions and holding the contents in suspension.

mixer, ribbon-blender **1.** A mixer that has helical ribbon-shaped blades that rotate close to the edge of a U-shaped vessel jacket and provide temperature control. It is used for relatively high-viscosity fluids and plastic dry blends, such as PVC calendering and extrusion compounds. **2.** An agitating device that consists of two or more metal ribbons that are pitched in opposite directions and spirally arranged around a central shaft. The curved and reverse-pitch ribbons operate on the principle of a screw, advancing the plastic forward by one ribbon and backward by another, resulting in efficient mixing.

mixer, sigma-blade A rotating agitator that is set horizontally in a kneading bowl or chamber that is used for mixing (plastics, bread doughs, and heavy pastes). The rotating blade or arm is shaped somewhat like the letter S or Z. Some units have two blades that overlap as they turn to provide maximum mixing action. See **blow molding, extruder reinforced-plastic.**

mixer, V-blender An adaptation of a tumbler. The V-units are made up of two cylindrical sections mitered to form the angle V. The theory is that as the mixing chambers turn, the material (usually powders, pellets, or other solids) is split between the two legs of the mixer. The legs recombine at the base of the V, where they split and combine again. With this flow pattern, they are especially effective when small amounts of additives are introduced into the mix. See **tumbling.**

mixer, vertical low-intensity A mixer that is designed around a vertical cylinder in which either a revolving screw or compressed air pressure is used to develop different flow patterns in the materials to be mixed. In the screw design, the screw conveys the material from the bottom of the cylinder through a central tube, where centrifugal force causes the material to fly off the screw flights and fall back onto the mass of material in the cylinder. Baffles located at the point where the material leaves the screw further aid mixing. When compressed air is involved, the air comes from the bottom of the mixing chamber and causes the material to spiral upward along the sides of the chamber and then down the center. Mixing cycles are short (on the order of 24 s). The mixer is recommended for high-volume automated mixing and handling operations.

mixing See **blender; compounding; material feeding and blending; material-blending letdown ratio; mixing theory; tumbling.**

mixing, dispersive The mixing of a fluid or plastic melt with a solid or unmelted plastic that exhibits a yield point. It involves the final melting of a plastic or breaking down an additive such as a pigment in the manufacture of color concentrate.

mixing, distributive The commingling of two fluids or plastic melts so that the scale of fluid separation reduces to where another process (diffusion or a chemical reaction) can occur. The mixing is in a laminar-flow regime, which is characteristic of NEAT plastics. It is distinguished by the deformation of the fluid interfaces as a result of the applied shear strain. Distributive mixing relates the amount of interfacial area growth to the fluid strain rate, as distinguished from dispersive mixing, which is a function of the magnitude of the stress. The latter accomplishes droplet and agglomerate breakup; the former is the distribution of those components. For example, it is aimed at achieving thermal and color uniformity where no solid breakdown is required.

mixing energy See **entropy of mixing.**

mixing evaluation A mixture can be described in terms of the statistical deviation of a suitable number of samples from a mean, the sample sizes being dependent on some length, volume, or area characteristics of the mixture or its properties. For example, if color imparted by adding pigment and homogeneity is measured by visual impression, the characteristic length is the resolving power of the eye—say, 0.001 inch. A completely mixed compound exhibits pigment streaks no greater than 0.001 inches. However, the color value for any given series of samples would appear uniform to a spectrophotometer that integrates over a 1 inch diameter circle even if the streaks were 0.1 inch thick. Likewise, the intensity of color difference between streaks would affect the resolving power of the eye or spectrophotometer and thus the characteristic length. The means of measuring are varied. In commercial practice, inspection of color homogeneity, streaks, or spots of unmixed filler or plastic is visual. Frequently, changes in properties, such as tensile strength, modulus, or density, are used to evaluate degree of mixing. See **plastic material selection; statistical assessment.**

mixing, impingement The mixing components via high-velocity turbulent contact of two or more streams. See **reaction injection molding, impingement mixing.**

mixing pin See **screw mixing, pin.**
mixing, shear roll See **compounding, shear-roll.**
mixing theory Theory of mixing considers a nonrandom or segregated mass of at least two components and their deformation by a laminar or shearing deformation process. The object of the shearing is to mix the mass in such a way that samples taken from the mass exhibit minimal variations, ultimately tending to be zero. The theory has three basic principles: (1) the interfacial area between different components must be greatly increased to decrease striation thickness, (2) elements of the interface must be distributed uniformly, and (3) the ratio of mix within any unit or the whole is the same. The mixing theory suffers from three limitations: (1) it is limited to purely viscous (Newtonian) materials, (2) it assumes no van der Waals or other forces between particles, and (3) the mixing process is assumed to be isothermal, and yet the heat generated usually is sufficiently high that the energy dissipation during mixing is considerable. Even though a major rheological gap exists between theory and practice, qualitative and semiquantitative concepts are obtained. See **rheology; van der Waals force.**
mix metering Accurately measuring materials as they pass into a hopper. Metering devices include augers, shuttle plates, venturis, and positive or negative weight belt feeders.
mixture A combination of two or more intermingled substances in which each component retains its essential original properties. See **admixture.**
mixture, continuous-phase The major component of a mixture or solution is called the *continuous* or *external phase,* and the minor component is called the *dispersed* or *internal phase.* The latter may or may not be uniformly dispersed in the continuous phase.
mixture, heterogeneous A mixture that has nonuniform composition consisting of dissimilar constituents separately identifiable. They have regions of unlike properties separated by internal boundaries. Note that not all nonhomogeneous materials are necessarily heterogeneous. See **equilibrium, heterogeneous; nucleation, heterogeneous.**
mixture, homogeneity The state of having uniform composition or structure. See **compounding; shear roll.**
modal **1.** Relating to or of a statistical mode. See **statistical mode.** **2.** Relating to a structure as opposed to a substance.
modeling Creating a model that is used in the complete evaluation of design, form, performance, and material processing. See **computer modeling; dimensioning and tolerancing, geometric; prototype.**
modeling, breadboard Assembly in rough form to prove the feasibility of a circuit, system, appearance, fit, or principle.
modeling, clay-up The application of clay to a model, which is eventually replaced by plastic or rubber.
modeling, cost See **technical cost modeling.**
modeling, Ellis See **viscosity, non-Newtonian flow Ellis model.**
modeling, nonlinear viscoelasticity See **Boltzmann superposition principle.**
modeling parametric Engineering systems previously defined parts in terms of exact geometry and now can use an alternative parametric system. This approach defines other information about a part, including relationships between intent and predictability, and manufacturing constrains. Solid geometry and other outputs are then derived from this information. To the design engineer, the system provides a flexible solid-system model that can be used in the early stages of product conceptualization, then modified and evolved into a complete design. To the design manager, it provides the first database that can correlate information from the design, documentation, analysis, and manufacturing functions to converge on a predictable product in the context of a single model. See **computerized knowledge-based engineering; computers; parametric.**
modeling pattern See **plaster of Paris.**
modeling plastic See **designing with plastic tailor-made models.**
modeling, rapid See **prototype, rapid.**
modeling, sintering See **laser sintering, selective.**
modeling, solid Computer-aided modeling of a part that is constructed by blending together primitive shapes, including cubes, spheres, cylinders, and wedges. It shows the complete surface of the product being designed.
modeling, stereolithography See **prototyping modeling, stereolithography.**
modeling, surface Computer-aided modeling of a part that is constructed by utilizing groups of connecting surfaces of many types, including swept, mesh, and revolution.
modeling, wire-frame Computer-aided modeling that is represented only by its edges.
modeling workflow See **manufacturing execution system.**
modem See **computer modem.**
Modern Plastics Magazine See **World of Plastics Reviews: *Modern Plastics* in the Year 2000.**
modifier A material that contains ingredients such as fillers, pigments, or other additives that improves processing or product performance. See **polymerization regulator.**
modulus The constant that denotes the relationship (ratio) between a physical effect and the force producing it. See **stress-strain curve.**
modulus and stiffness Stiffness is a measure of modulus with its relationship of load to deformation or the ratio between the applied stress and resulting strain. It is identified as stiffness (EI) = modulus (E) $\times$ moment of inertia (I). The term *stiffness* is often used when the relationship of stress-strain does not follow the modulus of elasticity's straight-line ratio. See **design, EI theory; moment of inertia; stiffness; stress-strain curve.**

modulus, apparent A convenient method of expressing creep that takes into account initial strain for an applied stress plus the amount of deformation or strain that occurs with time. See **creep modulus, apparent; strain; stress.**
modulus, bulk The ratio of a hydrostatic pressure to the volume of a strain. See **pressure, hydrostatic; strain.**
modulus, complex The ratio of stress to strain in which each is a vector that may be represented by a complex number. It may be measured in tension, flexure, compression, or shear. See **modulus, loss.**
modulus, compression The ratio of compressive stress to strain over the range for which this value is constant or below the proportional limit. See **proportional limit.**
modulus, dissipation factor The ratio of the loss modulus to static modulus of a material under dynamic load. It is proportional to damping capacity. Also called *loss tangent.* See **damping capacity; dynamic fatigue.**
modulus, dynamic The ratio of stress to strain under cyclic conditions that is calculated from either free or forced vibration tests in shear, compression, or tension. See **resonant forced vibration.**
modulus, elastic See **concavity factor; resonant force vibration.**
modulus, flexural The ratio, within the elastic limit, of the applied stress in flexure to the corresponding strain in the outermost area of the specimen. See **flexural, apparent; flexural property.**
modulus, initial The slope of the initial straight portion of a stress-strain or load-elongation curve. See **stress-strain curve.**
modulus, loss The dissipation of energy into heat when a material is deformed. It is a quantitative measure of energy dissipation that is defined as the ratio of stress at 90° out of phase with oscillating strain to the magnitude of strain. It can be measured in tension, compression, flexure, or shear. See **modulus, complex.**
modulus, mean The ratio of mean stress to mean strain. See **mean.**
modulus of elasticity The ratio of normal stress to corresponding strain (straight line) for stresses below the proportional limit of the material (Hooke's law); the ratio of stress to strain in a test specimen (tensile, compression, etc.) that is elastically deformed. Also called *modulus, Young's modulus, coefficient of elasticity*, or *E*. See **concavity factor; cross-linking network characteristic; design, EI theory; designing with the pseudoelastic method; proportional limit; quality factor, performance; vibration, free.**
modulus of elasticity, complex The vertical sum of *E* and the loss modulus, analogous to the complex dielectric constant. See **dielectric constant, complex; shear modulus, complex.**
modulus, offset The ratio of the yield stress to the extension at the offset point.
modulus of resilience The energy that can be absorbed per unit volume without creating a permanent distortion. It is calculated by integrating the stress-strain diagram from zero to the elastic limit and dividing by the original volume of the test specimen. See **stress, elastic-limit.**
modulus of rigidity The ratio of stress to strain within the elastic region for shear or torsional stress. Also called *shear modulus* or *torsional modulus*. See **torsional modulus of elasticity.**
modulus of rupture (MOR) The strength of a material as determined by flexural or torsional test. Also called *torsional strength.* See **flexural strength; torsional strength.**
modulus of rupture in bending The maximum tensile or compressive stress value, whichever causes failure, that is in the extreme plane of a beam loaded to failure in bending.
modulus of rupture in torsion The maximum shear stress that is in the extreme plane of a member of a cross-section loaded to failure in torsion.
modulus, oscillatory load See **dynamic mechanical measurement.**
modulus, secant The slope of a line drawn from the original to a point on the stress-strain curve for a material that corresponds to a particular strain. It is used in designing parts subjected to short-term, infrequent, intermittent stress of plastics in which the stress-strain is nonlinear. See **CAMPUS database; stress-strain curve; stress-strain ratio.**
modulus, shear See **modulus of rigidity.**
modulus, static The ratio of stress-to-strain under static conditions. It is calculated from static S-S tests in shear, tension, or compression and expressed in force per unit area. See **stress-strain curve.**
modulus, storage A quantitative measure of elastic properties that is defined as the ratio of the stress, in-phase with strain, to the magnitude of the strain. It can be measured in tension, flexure, compression, or shear.
modulus, stress-relaxation The ratio of the time-dependent stress to a fixed strain during stress relaxation of a viscoelastic (plastic) material. See **stress relaxation; viscoelasticity.**
modulus, tangent The slope of the line at a predefined point on a static-strain curve that is expressed in force per unit area per unit strain. This tangent modulus is at the point of shear, tension, or compression.
modulus, tension The ratio of tensile stress to the strain in the material over the range for which this value is constant.
modulus, theoretical See **plastics, theoretical versus actual values of.**
modulus time profile A plot of the modulus, damping, or both of a material versus time.
modulus, torsional See **modulus of rigidity; torsional pendulum.**
modulus, vibration See **resonant forced vibration.**
modulus versus specific gravity When plotting mod-

ulus of elasticity versus specific gravity, a straight-line ratio occurs for spruce wood, conventional reinforced plastics (not the superperformance RPs), aluminum, titanium, and steel.

modulus versus temperature See **rigidity, relative.**

modulus, Young's See **modulus of elasticity.**

modulus, Young's complex The vectorial sum of Young's modulus and the loss modulus.

Mohr circle A graphical representation of the stresses acting on the various planes at a given point. See **stress, plane.**

Mohr circle of stress A graphical representation of the components of stress and strain that acts across various planes at a given point and is drawn with reference to axes of normal stress (strain) and shear stress (strain). See **shear; strain; stress.**

Mohr envelope The envelope of a sequence of Mohr circles that represents conditions at failure for a given material.

Mohs hardness See **test, Mohs hardness.**

moire fringe analysis See **test, nondestructive moire fringe-analysis.**

moisture Water that is quantitatively determined by a prescribed method that may vary according to the nature of the material. See **deliquescence; desiccant; orange peel; water.**

moisture absorption Moisture from the atmosphere that penetrates the interior of plastics. This water vapor is drawn from the air only, as distinguished from water absorption that is the gain in weight due to the absorption of water by immersion. See **absorption; test, water-absorption; water absorption.**

moisture adsorption The surface retention of atmospheric moisture on plastics. See **adsorption; moisture.**

moisture absorption and temperature change See **hygrothermal effect.**

moisture analyzer A device that monitors, combats, and troubleshoots when quality problems involve moisture-sensitive plastics and additives.

moisture and drying See **test specimen.**

moisture content The moisture that is present in a material, as determined by a prescribe method and expressed as a percentage of the weight of the material on either of the following bases: (1) original weight, usually referred to as *moisture content*, or (2) moisture-free weight, usually referred to as *moisture regain*. The contamination of plastics with moisture or water has been a major problem. Different plastics require different procedures for drying. For example, the contents of 50 lb (23 kg) sealed bags of hygroscopic plastic are dried by the supplier of the plastic. If the fabricator uses only a few bags of the plastic, the remaining open bags may not be properly sealed because they are expected to be used shortly. In an area with high humidity, it does not take long for moisture to enter the bags and cause the plastics not to process properly. See **plastic, hygroscopic; test, reinforced-plastic moisture-content; test, water-absorption.**

moisture content equilibrium A steady-state condition that is obtained by the gain or loss of moisture when a material is exposed to an environment of a specific temperature and humidity. This equilibrium condition, independent of drying method or rate, is a material property. Only hygroscopic plastics have equilibrium moisture contents. See **plastic, hygroscopic.**

moisture content versus dew point Processors refer to moisture content in terms of percent, and dryers refer to dew point. For example, a 0.04% moisture content in air is only about −20°F (−30°C) dew point and a −40° F (−40°C) dew point is a moisture content of about 0.13%. See **dew point.**

moisture cure See **adhesive, moisture cure.**

moisture equilibrium The condition that is reached by a material when it no longer takes up moisture from or gives up moisture to the surrounding environment. See **absorption; desorption; adsorption.**

moisture, humectant agent An additive that has a pronounced effect on the ability of moisture to adhere to a substance. It is sometimes used in antistatic coatings for plastics such as polyalkoxythiophene plastic. See **antistatic agent.**

moisture penetration See **fiberglass binder/sizing coupling agent.**

moisture, regain The tendency of a material to pick up or give off ambient atmospheric moisture until it reaches an equilibrium moisture content at a given temperature and humidity level.

moisture resistance The ability of a material to resist absorbing moisture from air or when immersed in water.

moisture saturation See **deliquescence.**

moisture vapor transmission (MVT) The rate at which water vapor permeates through a plastic material (film, etc.) at a specified temperature and relative humidity.

mol See **mole.**

molar heat of fusion The number of moles of solute that are dissolved in 1 kg of solvent.

molar heat capacity The amount of heat that is required to raise 1 mole of a substance 1°F in temperature. Also called *molal heat capacity* or *molecular heat capacity*.

molar heat of fusion The energy that is required to melt 1 mole of solid. See **fusion.**

molar heat of sublimation The energy that is required to sublime (melt) 1 mole of a solid.

molar heat of vaporization The energy that is required to vaporize 1 mole of a liquid.

molar mass of a chemical compound The mass in grams that is numerically equal to the molecular mass of the compound. See **chemical compound.**

molar mass of an element The mass in grams that is numerically equal to the atomic mass of the element. See **element.**

molar solution Aqueous solution that contains 1 mole (gram-molecular weight) of solute in 1 liter of the solution. See **solution.**

molar susceptibility The magnetic susceptibility of a compound per gram-mole of that compound.
mold A cavity that is designed to form desired final shapes and sizes. A mold can be a sophisticated piece of machinery with many parts that require high-quality metals and precision machining. To capitalize on its advantages, the mold may incorporate several cavities. Many molds, particularly for injection molding, have been preengineered as standardized products that can be used to include cavities, different runner systems, cooling lines, and unscrewing mechanisms. See **blow-molding mold; compression molding; machining; mold; mold cavity, injection; reaction-injection molding; rotational molding; tooling.**
mold adapter plate The plate that holds the mold to the molding-machine press or platen.
mold, automatic A mold that goes repeatedly through its entire cycle, including ejection, without human assistance. See **operation, automatic; operation, manual; operation, secondary; operation, semiautomatic.**
mold back draft A detail of a molding that is smaller than the normal mouth opening of the mold. The opposite is a mold undercut.
mold backing plate A plate that is used to support cavity blocks, guide pins, bushings, and similar mold parts.
mold, balanced A mold that is designed with runners and cavities spaced and sized for uniform melt flow, fill, and packing pressure throughout the system.
mold base An assembly of usually steel plates that holds or retains the cavity.
mold base assembly, standardized See **mold, preengineered.**
mold bleed hole See **mold cavity venting.**
mold, blow-molding See **blow-molding, extruder, die; blow-molding mold.**
mold bluing A mild blemish in the form of a blue oxide film that occurs on the polished surface of a mold as a result of the use of abnormally high mold temperatures. See **bluing agent.**
mold bluing off Checking the accuracy of mold cutoff surfaces by putting a thin coating of Prussian blue on one-half and checking the blue transfer to the other half. Other techniques used include carbon paper or shims.
mold bottom plate The part of the mold that contains the heel radius and push ups (ejection mechanism). It is used to join the lower section of the mold to the platen.
mold breakaway See **clamping mold, slow breakaway.**
mold breathing **1.** The pause in the application of mold pressure when using plastics that gives off gases during the heating process; the removal of any entrapped air. This on-off-on pressure action occurs just prior to having the mold completely closed to allow the escape of gas or air. It is used with many thermoset plastics, vulcanizations of TS elastomers or rubbers, and any material that releases gases. Also called *mold bumping, dwell pause, dwell, gassing,* and *degassing*. See **cure, step; phenolic plastic; vacuum press; vent hole; venting. 2.** When referring to plastic sheeting, permeability to air. See **permeability; clamping preclose.**
mold bubblier See **mold-cooling channel bubbler.**
mold bumping See **mold breathing.**
mold cam bar The stationary angled bar or rod that is used to mechanically operate the slides on a mold for side-action core pulls.
mold cavity The space between matched molds that encloses the molded part. It is the depression in the mold that forms the outer surface of the molded part. There can be single or multiple cavities in one mold. Also called *die* or *tool*. See **mold cavity, compression; mold cavity, injection; mold unit.**
mold-cavity chase **1.** An enclosure that is used to shrink-fit parts of a mold cavity in place to prevent spreading or distortion in hobbing. **2.** To enclose an assembly of two or more parts of a split cavity block.
mold-cavity coating When molding or extruding corrosive reacting plastics such as CPVC parts of the mold cavity, cores, or insets (also in dies), the metal surfaces can be subjected to corrosion and pitting. Certain steels, such as stainless steel, can provide a degree of protection. Hard coatings such as physical vapor deposition (PVD) of TiN, TiCN, and TiAiN are extremely corrosion resistant and provide excellent abrasion resistance. They also enhance molded part release. Various coating systems are used to protect the metal cavity's polished surface or extend its useful life based on the plastic being processed. They boost lubricity while avoiding melt adhesion problems. More prevalent are chromium-based materials that can be applied at rather low temperatures to provide resistance to corrosion, abrasion, or erosion if needed, such as pure Cr, CrN (chromium nitride), and CrC (chromium carbide). Some coatings such as PVD and chemical vapor deposition (CVD) subject the mold steels to excessively high temperatures that reduce steel hardness. Systems have been developed with PVD and CVD that operate at lower temperatures of 200 to 400°C (400 to 750°F), such as plasma CVD (PCVD). Popular is the so-called nitrided coating; it is actually a hardened nitride casing (nitrogen is absorbed into the surface of the steel). See **chrome plating; corrosion resistance; gold; pit; screw coating; wear.**
mold cavity, compression The male cavity is designed as a plug that fits into the female cavity so that the mold action during closing provides a hydraulic pressure loading. The tight-fitting male plug literally acts as a hydraulic ram. See **clamping; compression molding; mold cavity, injection.**
mold-cavity cost Molds in general are expensive, with the major cost principally in machine-building labor. The materials that are used to construct the cavity, core, and other components determine the quality, performance, and longevity (number of parts to be processed) of a mold. Also needed are good machinability of component metal parts, material that will accept the desired finish (polished, textured, etc.), the ability to transfer heat rapidly and

evenly, and the ability to endure sustained production without constant maintenance. Using low-cost material to meet high performance requirements will compromise mold integrity. For example, for more than 90% of the molds, the cost of the cavity and core materials is less than 5% of the total mold cost. See **cost, product; mold cost.**

mold cavity, debossed. Depressed or indented lettering or designs in the cavity that produce bossed impressions on the molded part. See **decorating, fill-and-wipe.**

mold-cavity deposit A plastic build-up on a cavity's surface that is due to plate out of the plastic and usually is attributed to the use of certain additives.

mold-cavity draft On most molded parts, features must be cut into the surface of the mold perpendicular to the molding parting line. To properly release the part from the tool, parts almost always include a taper. The amount of mold draft required will depend on factors such as type of plastic being processed, processing conditions, and surface finish. For example, a highly polished surface will require less than an unpolished mold. Any surface texture will increase the draft at least 1° per side for every 0.001 in. (0.003 cm) depth of texture. Special mold-cavity surface action can be used. Elastomeric material has a rubbery condition and may not require the draft for ejection. Also called *draft in the direction of the mold.* See **mold-parting line; mold release agent.**

mold cavity, duplicate-plate A removable plate that retains cavities and is used where a two-plate operation is necessary for loading inserts.

mold cavity, etched A surface that is treated with an acid, leaving relief to form the desired design texture on the molded part. See **chemical etching; photoetching tool; surface treatment; texturizing.**

mold-cavity ejector Various mechanical means that are used to eject or remove the molded part from the cavity.

mold cavity, female The indented half of a mold that is designed to receive the male half. See **mold cavity, male.**

mold-cavity fill and pack See **injection molding, boost cut-off or two-stage control.**

mold-cavity filling See **mold-filling monitoring.**

mold-cavity finish, SPI/SPE Mold Standard See **surface finish.**

mold cavity, frozen-layer Plastic melt begins to "freeze" (solidify) as it fills an injection-molding mold cavity. The frozen layer can easily vary in thickness as the mold fills, producing different frictional shear forces. As a result, flow (filling) and solidification (thermoplastic cooling) should be evaluated together. See **freeze-off.**

mold-cavity grit blasting Blowing steel grit or sand onto the cavity wall to produce a rough surface. This surface treatment may be required to permit air to leave the mold during molding or to provide a desired surface finish on the part. See **cleaning, abrasion.**

mold-cavity hobbing Forming single or multiple mold cavities by forcing a hob into a relatively soft steel blank. Hobbing is a technique where a master model in hardened steel is used to sink the shape of the cavity into a heated mild steel, such as beryllium copper. The hob is larger than the finished plastic molded part because after hobbing, the metal shrinks during cooling. See **electro-erosive cutting and sinking.**

mold-cavity honing Using a fine-grained whetstone or equivalent to obtain precise accuracy of the surface finish.

mold cavity, injection The two halves of the mold have a flat parting line. When the two halves meet, each half is literally making contact by one flat surface against another flat surface. Pressure on the injected melt in the cavity is through the plasticator's pressure-ram action on the melt. See **clamping; mold cavity, compression; molding pressure required.**

mold-cavity land The length in the different gate configurations that influence melt flow.

mold cavity, male The extended half of a mold that is designed to match the female half. Also called *plunger.* See **mold-cavity filling.**

mold-cavity melt-flow analysis A comprehensive understanding of the mold filling process. Detailed information is generated concerning the influence of mold-filling conditions on the distribution flow patterns, flow vectors, shear stresses, frozen skin, temperatures, and pressures. From these data, conclusions regarding expected tolerances as well as part quality strength, appearance, and weld line can be drawn. The likelihood of warping surface, blemishes, and strength reductions due to high shear stress can be anticipated. On this analysis, the best and most practical mold-filling conditions can be selected. See **flow model; injection-molding melt flow; injection molding process-control parameter; melt-flow analysis; processing fundamental; temperature transition.**

mold-cavity melt fountain flow The melt pattern that enters the cavity (injection molding) by forming a fountain (balloon) stretching effect. The stretching melt-front-oriented outer surface covers the inside wall of the cavity. Melt that follows basically fills in the fountain flow. The result is a nonuniform orientation in the cross-section of the molded part; however, parts can still meet part performance requirements. The degree of ballooning or bubble formation is controllable so that specific desired properties can be obtained. See **injection-molding melt flow.**

mold-cavity packing See **cushion; mold-filling monitoring; packing factor.**

mold-cavity plating See **mold-cavity coating.**

mold-cavity pressure The cavity pressure can be recorded via a transducer such as one being located in the cavity near the gate. It can plot a profile that records different information such as filling, packing, and holding pressures. See **injection molding mold-cavity pressure; injection molding, programmed; molding pressure, required.**

mold-cavity register An angle face on the mold that

matches another when the mold halves are closed to ensure their correct alignment.
mold-cavity retainer plate A plate that is at the mold parting line and usually contains the guide pins and bushings that line up the two halves of the mold. It holds the inserted cavities in a mold.
mold cavity, split A cavity that is made in sections.
mold cavity, split-ring A mold in which a split-cavity block is assembled in a chase to permit the forming of undercuts in a molded part. The block, along with the molded parts is ejected from the mold and then separated.
mold-cavity surface The surface of the mold cavity that faces and reproduces its surface condition on a molded part. A significant advantage of the molding processes is that they mold surface polish and textures into the part. No secondary surface-finishing operations are required unless special finishes such as plating or hot stamping are necessary. High-gloss, dull, matte, and textured finishes (as well as their combinations) on parts are feasible. See **chrome plating; molded-material surface measurement; polish; surface finish.**
mold cavity, unbalanced A nonuniform layout of cavity and runner sizes or locations that will potentially cause a nonuniform melt-fill rate, packing pressure, and part quality unless the design incorporates the proper runner, gate, and cooling system. It usually is used in molding noncritical parts since balancing the melt flow can become difficult.
mold-cavity unit A cavity insert that is designed for quick interchangeability with other cavity inserts.
mold-cavity venting Shallow channels or minute holes in the cavity or in the mold parting line that allow air and other gases that may form during processing escape. See **bleed; mold venting, water transfer; screw venting; vent bleed.**
mold-cavity well See **mold, compression, plastic material well.**
mold change, quick (QMC) Removing as an example, the mold in different fabricating machines, particularly injection molding, and replacing it automatically with another one in a matter of minutes; also transfer to storage. Devices such as slotted or shouldered bars assembled in a molding machine are designed to allow the removing and loading of molds. The machine microprocessor controls can be programmed to change the feeding of materials and process controls with the quick change. See **robot.**
mold chase An enclosure of any shape that is used to (1) shrink fit a mold cavity in place, (2) prevent spreading or distortion in hobbing, or (3) enclose an assembly of two or more parts of a split block. See **mold, split-ring.**
mold chase, floating A mold member that is free to move, that fits over a cavity or a lower plug, and that fits into an upper plug telescope.
mold, chunk An open-face mold.
mold circuit board See **injection molding circuit board.**
mold classification by operation See **operation, automatic; operation, manual; operation, secondary; operation, semiautomatic.**
mold cleaning Mechanical cleaning, such as separating the residual cured plastic, is usually confined to simple, uncomplicated molds. Thermal, chemical, and solvent bath methods are generally used and require the proper equipment to entrap pollutants. Proper precaution is taken not to damage molds. For example, mold (or die, screw, etc.) damage may occur if flammable components of the plastics burn up in an oxygen-containing enclosure and cause uncontrolled exothermic combustion. See **aerated sand cleaning, hot; cleaning.**
mold coating See **tooling, coat.**
mold, cold runner See **mold runner.**
mold cold slug See **molding cold slug.**
mold, collapsible-core A collapsible or expandable core that provides a means to mold internal threads, undercuts (as in tamperproof bottle caps, etc.), protrusions, and cut-outs. Various patent-approved design systems are used. Popular steel designs have a center pin (with taper and flange sides), a collapsible core (the heart of the system), and a sleeve (backup unit to collapse the core segments if they fail). The core is a hollow cylinder with slots that are parallel to the cylinder axis. These flexings form (machined for a thread, etc.) the undercut. When in the mold position prior to molding, the center pin expands the flexible slot segments; after molding, the pin is released, which permits the molded part to be ejected from the mold. See **medical seal and closure.**
mold, combination See **mold, family.**
mold component See **mold, preengineered.**
mold, compression The typical two-part mold has a female cavity with a matching male plug cavity that fits into the female cavity. In the closed position, the space located between the mating cavities allows the molding material to be compressed. With the usual thermoset plastic used, flash occurs. See **mold, semipositive; thermoset plastic.**
mold, compression flash ring The clearance between the force male plug and the vertical or horizontal wall of the female cavity in a positive or semipositive mold. It is the ring of excess melt that escapes from the cavity into this clearance space. See **mold flash.**
mold compression force The male half of the mold that enters the cavity, exerts pressure on the plastic, and causes it to flow. Also called *punch, plunger,* or *ram.*
mold, compression, plastic material well Space that is provided in the cavity to handle the bulk factor of the material being loaded in the female cavity.
mold, compression shear-edge A feature, such as for reinforced-plastic materials (SMC, etc.), that has a telescoping shear edge located around the periphery of the mold cavity. It seals off the mold when closed, releases or vents air and gases from the mold cavity, and permits the cavity half of the mold to slide over the core half so the required pressure can be applied to the material. To control part dimensions, it is important to control the material

charge size, weight and volume. See **bulk-molding compound; material charge; sheet molding compound.**

mold condensation See **mold dehumidification.**

mold contractional obligations See **legal matter: mold contractional obligation.**

mold control See **injection molding process-control parting line; process control.**

mold cooling Controlled cooling of the mold for thermoplastics is an essential mold feature and requires special attention in mold design. The usual water-cooling medium requires that it be in turbulent flow, rather than laminar flow, to transfer heat out of the molded part at a much faster rate. See **baffle; coolant; design mold; design-mold basics of flow; mold heating; mold water channel; Reynold's number; temperature controller; water, hard; water, magnetic; water softening.**

mold cooling baffle Ribs or plugs that are used to provide uniform cooling action within the mold.

mold cooling channel bubbler A device that is inserted into a mold cavity to allow water to flow deep inside the cavity into which it is inserted and also discharged. Uniform cooling can be developed, which is needed for processing reinforced plastics in open molds.

mold cooling, flood An internal flooding action in a confined open chest that surrounds the mold cavity rather than using drilled holes. Drilled hole systems are also used. It is used particularly in blow-molding molds. See **blow-molding mold.**

mold cooling, flow meter A device that can be put in-line with supply and return water to measure temperature, pressure, and flow rate of water through the mold.

mold cooling/heating **1.** Circulating a cooling medium (of water with or without ethylene glycol when processing thermoplastics) through channels or passageways located within the body of the mold to solidify the TP melt into a molded part. See **coolant; ethylene glycol; heat pipe.** **2.** With thermoset plastics, heating the mold can be accomplished by circulating steam, hot oil, or other heated fluid, but the usual method involves inserting electrical heating elements or probes into the mold. A few TSs may require the higher heat to complete their cure. See **coolant; thermoset plastic.**

mold cooling, pulse Conventional continuous coolant flow mold-temperature control generates the temperature gradients called isotherms (contour or wavy lines that move around the cooling channels). Although heat travels from the plastic to the metal to the coolant quickly, the mass of steel between the channels goes unused. Because it is not continuous, pulse cooling eliminates the isotherms that segregate a conventionally cooled mold. Heat from the part is absorbed not only by the cooling channels but also by the large mass of steel on the shop-side of the mold. When the fill stage is complete, coolant circulates quickly, removing excess heat and quickly bringing the mold and part back to minimum temperature. It is a cyclic process that is targeted to reduce cycle time 6 to 10%, less molded-in stress, reduced scrap, and reduced energy use. See **injection molding melt-pulse cooling.**

mold-cooling rate A variable that influences factors such as melt-flow rate, residual stress, and degree of orientation. It is usually the final control in the variables associated with plastic part performance. Heating and cooling rates for amorphous and crystalline plastics differ; if not properly controlled, part performances either do not meet maximums or they are defective. See **amorphous plastic; crystalline plastic; melt flow; orientation; stress, residual; temperature controller.**

mold cooling scale See **scale; water, magnetic.**

mold cooling, spiral A method of mold cooling in which the cooling medium flows through a spiral cooling cavity in the body of the mold.

mold cooling temperature Lowering coolant temperature below the required level is supposed to speed up heat removal; actually, the reverse is often true. Lowering temperature reduces water chiller capacity. If possible, avoid temperatures below 40°F (4°C) since ethylene glycol is added to the water to prevent water freezing. Going lower requires more EG, which creates a more viscous solution, resulting in greater pumping power required and higher costs. See **ethylene glycol; Reynold's number; temperature.**

mold cooling time In addition to the cost of plastic material and machine costs, the final cost to mold a part interrelates with the molding cycle. A large part of this cycle, up to 80%, is due to the time required to cool the part in the mold. Thus, the target is to reduce cooling time while recognizing that heat transfer through plastics has its limitations. See **mold dehumidification.**

mold cooling, vacuum See **mold venting, water transfer.**

mold core **1.** A channel in a mold for circulation of a heat-transfer media. **2.** Part of a complex mold that molds undercut parts. Cores are usually withdrawn to one side before the main sections of the mold open. They have passages for heat transfer to the melt in the cavity. Also called *core pin.* See **core; heat pipe.**

mold cored A mold that incorporates ducts that permit the passage of heating and cooling services.

mold-core pin A pin that is used to mold a hole in the molded part.

mold coring, side A projection that is used to core a hole (or other shape) in a direction other than the line of closing a mold. It is withdrawn before the part is ejected or prior to the mold opening. Also called *side draw pin* or *cam pin action.* See **mold side action.**

mold corner Corners should be as generous as possible. Sharp corners (radii and fillets) can interfere with smooth melt flow and create possibilities for melt turbulence. Examples of problems that can develop include surface defects and stress concentrations.

mold corrosion See **mold-cavity coating.**

mold cost Up to about 12 to 20% of mold cost is for the (raw) material used to manufacturer the mold; mold design is about 5 to 10%; mold building hours are about 40 to 60%; and profit is about 5 to 10%. See **mold-cavity cost; product.**

mold cut-off The part of the mold land that isolates the molding. Also called *shut-off* or *flash land.*

mold decorating, fill and wipe See **decorating, fill-and-wipe.**

mold decorating, in-mold See **in-mold decorating; molded lettering and surface decoration.**

mold, deep-draw A mold's core cavity is much longer than its wall thickness.

mold deformation After the molding pressure stroke and during any after-fill, pressure is built up in the mold cavity. During injection molding this pressure is generally one-third to one-half of the pressure in the IM machine plasticator. Such pressure can cause elastic deformation, such as bending of the cavity retainer plates and cores, ejector, and guide pins. To reduce this action, sturdy construction of the mold is required. However, the goal is to minimize the amount of mold material since light construction is usually desired for efficient cooling. See **deformation.**

mold degating See **mold-gate degating.**

mold dehumidification When chilled water is used as a heat-transfer medium during high humidity periods, condensation may form on the surface of the mold and cause imperfections on the molded part. Chilled water can reduce cycle time, so alternate methods can be used to eliminate condensation, such as enclosing the mold with dehumidified dry air and high-velocity dry airstream. See **condensation; dehumidifier; desiccant drier; mold cooling time.**

mold dowel A metal pin that is located in one-half of a mold and that enters a corresponding hole in the other half so that, on closure of the mold, the two halves become correctly aligned. Also called *mold pin* or *retaining pin.*

mold dowel bushing A hardened steel bushing that lines a dowel hole. See **mold pin.**

mold draft See **mold-cavity draft.**

molded air lock A surface depression on a molded part that is caused by trapped air between the mold surface and the plastic material during processing. See **air entrapment.**

molded, dry as (DAM) The condition of a part immediately after it is removed from a mold and allowed to cool.

molded edge An edge that is not physically altered after molding for use in its final form.

molded ejection mark A surface mark on the part that is caused by the ejector pin when it pushes the part out of the mold cavity. See **mold ejector.**

molded flash line A raised line that appears on the surface of a molded parting line.

molded gate mark A surface discontinuity on a molded part that is caused by the gate. See **mold gate.**

molded gate splay A fanlike surface defect near the gate on a part that is usually due to turbulent melt flow. Also called *silver streaking.*

molded-in insert See **fastener, mechanical; insert molding.**

molded-in thread A mechanical assembly method in which internal or external threads are molded into plastic parts. See **insert.**

molded lettering and surface decoration Lettering and other raised or depressed surface decorations and textures are easily incorporated on plastic products. The mold cavities can be machined, hubbed, or cast. See **in-mold decorating.**

molded material surface measurement The National Research Council of Canada's Industrial Materials Institute uses computerized ultrasonic technology for accurate, nonintrusive, and nondestructive measurement of the surface and interior of molding materials during the filling, packing, holding, and cooling phases of injection molding. The system uses pulse-echo ultrasonic techniques similar in principle to those used for an expectant mother's sonogram to listen through tool steel and see parts as they are being molded. For example, when the ultrasonic waves meet the acoustic-resistance boundary between the two different media of the mold and plastic, an air gap is formed when the cooling part shrinks and some of the energy is transmitted through the boundary. The rest of the energy is reflected back to an ultrasonic transmitter. No mold modification is needed. See **accuracy; deviation; measurement.**

molded, net A molded part that does not require additional processing to meet dimensional requirements.

molded part coring The removal of excess plastic from the cross-section of a molded part to obtain a more uniform wall thickness.

molded part cosmetics The Molders Division of SPI publishes a bulletin entitled *Cosmetic Specifications of Injection Molded Parts* that provides quantitative definitions and recommended methods of inspection and measurement of cosmetic attributes in the absence of customer-provided specifications. It provides guidelines for defects such as black specks and flow lines. See **defect.**

molded part ejection Ejection is through a mechanical knock-out device. See **mold ejector.** To aid the removal of certain parts, particularly if they are large, air is forced between the molded part and cavity wall.

molded part, milligram See **injection molding, micro-.**

molded part separator A machine or system that is used to separate parts from the runner system.

molded part setting-up The hardening of material in the mold prior to removal of the molding. Also called *set-up.* See **annealing.**

molded part shape, complex A molded part with undercuts that prevent the part from being released in the direction of the mold opening. It requires a mold with side actions/cores, rotating cores, loose cores or inserts, more than one parting line, wedges, or other devices. The choice of method, or a combination of these methods, depends on the shape and the properties of the plastic (flexible to rigid, shrinkage, etc.) and also the standard of quality required, such as not having a parting line at a certain location.

molded-part shrinkage See **design, melt-flow Cauchy-Riemann differential equation; shrinkage.**

molded part surface See **molded material surface measurement.**

molded part thickness See **optical monitoring.**

molded screw thread Three basic methods are used to mold screw threads: (1) use a core that is rotated after the molding cycle has been completed thus unscrewing the part; (2) put the axis of the screw (only for external threads) at the mold parting line where potential flash can occur and a parting line could exist; and (3) make the threads few, shallow, and of rounded form so that the part can be stripped from the mold without unscrewing. See **insert molding.**

molded surface See **orange peel.**

molded taper, back The reverse draft or undercut used in a mold to prevent molded parts from being removed from the mold freely.

molded threaded fastener A fastener or insert, usually metal, that is molded into the part during the molding process. See **insert molding.**

molded undercut They are used but may require sliding cores or split molds. External undercuts can be placed at the parting line to obviate the need for core pins. Shallow undercuts often may be stripped from the mold without need for core pulls. If the undercut is strippable, the other half of the mold must be removed first. Then the mold ejector pins can act to strip the part.

mold ejector An attached mold assembly for operating ejection pins or pads to eject the molded part from the cavity. It may operate mechanically, hydraulically, pneumatically, or electronically. See **clamping close-position ejector mechanism; molded-part ejection.**

mold-ejector mark A surface mark on the part that is caused by the ejector, such as pins, when the part is pushed out of the mold. See **molded gate mark.**

mold-ejector pin The pin (as well as other mechanical devices, such as a rod, sleeve, or stripper plate, that are attached to a plate or bar) pushes the molded part out of the mold after the mold starts opening. Also called *knockout pin.*

mold-ejector ram A controllable, small, mechanically, hydraulically or electrically operated ram that is fitted to the molding press for the purpose of operating the ejection mechanism.

mold-ejector return pin It is a projection that pushes the ejector assembly back as the mold closes. Also called *surface pin, safety pin,* or *position pushback.*

mold, elastomeric An elastic or stretchable mold that is made of rubber (elastomer), rather than the usual steel, so that complex shaped parts can be removed without mold side actions. Usually it is used for casting plastics. It can be stretched—for example, to remove cured parts having undercuts. See **elastomeric mold; latex; reinforced plastic.**

mold, electroformed See **electroforming.**

molder A company that is capable of providing molding services to a customer.

molder, captive See **processor, captive.**

molder certification See **processor certification.**

molder contractional obligation See **legal matter: mold contractional obligation.**

molder, custom See **processor, custom.**

molder, proprietary See **processor, proprietary.**

mold eyebolt and hole A hole that is located in a mold and used to lift and move molds (also dies and other tools). Balanced lifting occurs with proper use of eyebolts; safety devices are incorporated to ensure that no accidental dropping occurs to protect personnel and the mold. The various bolts have different safety load-carrying capacities.

mold, expandable polystyrene See **expandable polystyrene.**

mold, family **1.** A multicavity mold where each forms a part that often has a direct relationship in usage to the other parts in the mold. **2.** Mold in which parts from different customers are grouped together in one mold for economy of production.

mold-feed pushing Hardened steel bushing in an injection mold that forms a seal between the mold and injection unit.

mold, female See **mold cavity, female.**

mold, ferris wheel Mold halves that are attached to a rotating platen. When the platens close, each mold cavity receives melt in a sequence pattern. For example, an automobile acrylic taillight requires three molds. The first mold receives the amber color, the second receives the yellow color, and the third receives the transparent that not only fills its respective cavity opening but also can cover the complete light plate to ensure that no moisture or rain leakage enters when in service. See **Velcro strip.**

mold filling, foam See **test, foam-pressure.**

mold filling hesitation To understand the "hesitation effect" consider the flow patterns throughout injection-molding filling. The melt first enters from the gate, and the flow front reaches the first thin wall section. There is insufficient pressure to fill this thin section because the melt has an alternate route along the thick section. Melt that just entered the thin section sits losing heat until the rest of the mold is filled. When the mold is almost completely filled, the full injection pressure is available to try to fill the thin section. However, the melt in the thin section has frozen, and the thin section is not filled. This problem is caused by the fast/slow/fast (hesitation) filling speed that is used. If the melt continues to flow at a relatively steady or uniform rate, there is no difficulty in filling the thin section. See **melt.**

mold filling monitoring Flow-front speed during filling is commonly inferred either from screw position or cavity-pressure sensors. The quality of the final molded part, however, is determined by the actual flows of molten plastic into the cavity to pack the melt. Ultrasonic technique is an example of monitoring the filling action. This technology includes the use of ultrasonic transducers and software to verify mold-filling patterns and measure flow-front speeds. It identifies exactly when mold cavities are filled and allows switching from injection pressure to packing pressure to save energy. Ultrasonic beams are emitted from transducers that are installed at the external surfaces of a steel mold cavity. The beams propagate in the steel mold cavity interface. Before the melt arrives at the transducer's position, ultrasonic energy is totally reflected at this interface. After the melt's arrival, part of the beam energy is transmitted into the melt, indicating that the melt front has arrived. The sensor can monitor the gap caused by the shrinkage of the part away from the mold wall, as well as measure the speed of the gap's development. Ultrasonic waveforms show echoes in the solidifying parts, which can be used to obtain temperature profiles across the melt and to study cooling efficiency. See **cushion; energy conservation; injection molding melt flow; mold-cavity melt flow analysis; mold-gate size; packing factor.**

mold finish See **mold cavity surface.**

mold flash **1.** A type mold that has a land surface that permits the escape of excess molding material and has no trimming action. Such a molding material relies on back-pressure to seal the mold and put the part under pressure. See **back pressure; material, biscuit. 2.** The portion of material that protrudes beyond the edge of the finished molding. It is attached to a molding along the mold's parting line, holes, or openings. It principally occurs with thermoset plastics. With most parts it is objectionable and must be removed manually or deflashed by barreling or tumbling, buffing, grinding, and blasting. See **compression molding; deflashing; flash; mold-gate size; molding flash line; operation, secondary; spin trimming; trim; tumbling.**

mold flash ring See **mold, compression flash ring.**

mold, flash trap A molded-in lip or blind recess on a part that is used for trapping excess melt (flash).

mold, flexible See **mold, elastomeric.**

mold flooding See **mold cooling, flood.**

mold flow analysis See **design mold.**

mold force plug See **mold compression force.**

mold, French A two-piece mold for irregular shapes that are tall, top heavy, leaning to one side, or extremely detailed.

mold gate The orifice through which the melt flows and enters a mold cavity. Single gate or multigates can be used for a single cavity. The gate can have a variety of configurations to meet different melt-flow requirements and cavity configurations. See **design mold; injection-molding mold; mold-gate size.**

mold-gate blush A blemish or disturbance in the gate area that is associated with melt fracture around the gate from stresses caused by process conditions and mold geometry. This problem, can be eliminated or reduced by raising the melt temperature, reducing injection speed, checking the gate for sharp edges, enlarging the gate, and checking that the runner system has a cold-slug well. See **blush; melt fracture; mold-ejector mark; mold-gate mark; molding cold slug.**

mold-gate center The gated mold has the cavity filled through a sprue or gate directly into the center of the part.

mold-gate cosmetic See **mold gate, valve.**

mold-gate degating The removal of the gate from the molding by automatic or manual means within the mold during molding or after the part is removed from the mold.

mold gate, diaphragm A gate that is used in molding annular or tubular parts. The gate forms a solid web across the opening of the part. Also called a *disc* or *web gate.*

mold gate, direct A gate that has the same cross-section as that of the runner. See **mold runner.**

mold gate, edge A gate that uses a heater coil or rod and single- or multiple-edge gate openings.

mold-gate fan The opening between the runner and the mold cavity that has a shape of a fan. This shape helps to reduce stress concentrations in the gate area by spreading the opening over a wider range.

mold-gate flash Usually a long, shallow, rectangular gate that extends from a runner that runs parallel to an edge of a molded part along the flash or mold parting line.

mold-gate location The gate should be located at the thickest part of the molding, preferably at a spot where the function and appearance of the molding are not important. The location of the gate affects mold construction and the properties and appearance of the molding. The gate must be located in a way that ensures rapid and uniform mold filling and allows the air present in the cavity to escape during injection. If this requirement is not fulfilled, either short shots or burnt spots in or on the molding will be produced. See **mold filling monitoring; mold-gate size.**

mold-gate mark A surface discontinuity on a molded part that is caused by the gate through which material enters the cavity. See **mold-ejector mark; mold-gate blush; mold-gate scar.**

mold-gate nozzle A nozzle whose tip is part of the mold cavity and thus feeds the injection-molding melt directly into the cavity, eliminating the need for sprue and runner systems. The nozzle becomes the mold gate. See **injection molding.**

mold gate, pinpoint A restricted opening/orifice of 0.03 in. (3.3 mm) or less in diameter through which melt flows. This small gate minimizes the size of the mark left on a molded part. The gate breaks clean when the part is ejected. Also called *restricted gate.*

mold gate, ring A gate that encircles the core to permit the melt to move around the core symmetrically before filling the cavity and thus prevent a weld. It is used on cylindrical shapes. There are external and internal (with respect to the cavity) ring gates.

mold-gate scar A scar in the gate area that occurs if the gate is too large. Larger sizes permit faster fill and cycle times. See **mold-gate mark.**

mold-gate size The gate size has a tremendous effect on the success or failure of attempts to produce high-quality parts economically. The cooler the melt, the more viscous it becomes; the more viscous it becomes, the more difficult it is to move the melt through very small gate orifices. High injection pressure is then needed to move the melt through the gate. The higher the pressure, the smaller the total area of the mold must be, otherwise high pressure will result in flash when processing thermoplastics or thermoset plastics. Another approach to reducing melt viscosity is to raise the melt temperature, which results in an increase in cycle time. Gate size is usually the critical factor that dictates the final mold-filling speed. See **cycle; mold flash; mold-gate location.**

mold gate, spider The multigating through a system of radial runners from the sprue.

mold-gate strain A strain that develops in the plastic at the part location of the gate. If the cooling rate of the melt is reduced to relieve this strain, cycle time increases. See **die spider; mold gate, tab.**

mold gate, submarine A type of edge gating where the opening from the runner into the mold is located below the parting line or mold surface. In conventional-edge and other gates, the opening is machined into the surface of the mold on the mold-parting line. With submarine gates, the molded part is cut by the mold from the runner system on ejection of the part. Also called *tunnel gate.*

mold gate, tab A small removable tab that is approximately the same thickness as the molded part and is usually located perpendicular to the part. It is used as a site for the edge gating location on parts with large flat sections. It also can be used as a site for gating so that if any unacceptable blemishes appear, they will be on the tab that is cut off. See **mold-gate strain.**

mold-gate tip, reverse With reverse gating, the gate mark is hidden. The mold is designed so that the gate location is on the core side or opposite the cosmetic surface.

mold gate, valve (VG) A valve gate is used in injection molds to provide a wider processing window of operation, provide better product quality, eliminate gate freezing, and be cost effective. The valve usually has a pin to mechanically open and close the gate orifice. An actuating mechanism (spring, adjustable air cushion, mechanical cam, pneumatic or hydraulic pistons, etc.) coordinates the movement of the pin with the molding cycle. This technique is considered when meeting demanding cavity-melt packing requirements where precise part weight or dimensions are required.

mold gate, valve feed control In hot runner molds valves can be controlled in a closed-loop. For example, the dynamic valve made by the Dynisco/Kona Hot Runner Group can be adjusted to partially open or close to eliminate unbalanced cavity fill. The conventional system requires tweaking and adjustments of the transfer position, injection pressures, and pack hold times and pressures until the defects in the part are minimized or eliminated. With dynamic feed, the valve can be individually adjusted (set) to deliver less melt at individually controlled lower pressure to eliminate flash, increase hold pressure, eliminate sink, and position weld. A transducer between each valve and gate is used to measure melt pressure as it enters the cavity. The user programs into a controller the time and pressure profile that is desired to fill the part properly. In doing so, variations in viscosity are negated. See **injection-molding melt flow.**

mold gel coating See **mold-cavity coating.**

mold grid The construction of channel-shaped supporting members within a mold.

mold guide pin See **mold-leader pin and bushing.**

mold half Each part of a mold is called a mold half, which usually does not mean that the mold is divided dimensionally into two equal halves. See **mold-parting line.**

mold, hand A small mold that is removed by hand from the press for the purpose of stripping molded parts or reloading (plastic or inserts). The operator manually removes a mold and removes the part. Also called *portable* or *loose mold.*

mold heating Controlled heating of the mold for thermoset plastics is an essential mold feature and requires special attention in mold design. See **design, die; design, basics-of-flow die; mold cooling; temperature controller; thermoset plastic.**

mold heat-transfer device A device that transfers localized heat to a heat sink to improve mold cooling or transfer heat from the source to a localized area such as hot sprue bushings. See **chill; heat pipe; thermodynamic properties.**

mold height The vertical distance of a closed mold that is located on a table so that the parting line is in a horizontal position. Most molds are put in horizontally operating machines (injection molding, blow molding, etc.), so the height actually is the horizontal distance from platen to platen with the mold closed.

mold hobbing See **mold-cavity hobbing.**

mold hold-down groove A small groove that is cut into the side wall of the mold cavity surface to assist in holding the molded part in the cavity while the mold opens.

mold, hollow A mold that permits melted plastic to be applied to its inside surface to form hollow shaped parts. See **blow molding; casting; rotational molding.**

mold, hot runner See **mold, runner.**

mold impression The part of a mold that imparts shape to the molding. See **mold cavity.**

mold inching The reduction in rate of mold closing travel just before the mating mold surfaces touch each other. See **compression molding inching.**

molding The forming or shaping of a material by a molding process. See **blow molding; casting; com-**

pression molding; encapsulation; fabricating process type; injection molding; reaction-injection molding; rotational molding.

molding and blending plastic See **blender.**

molding area diagram (MAD) A diagram that plots at least injection pressure (ram pressure) with mold temperature to provide the best combination of pressure and mold temperature necessary to produce quality parts. The MAD is a dramatic and easily comprehensive visual aid for analyzing these variables. Within the diagram area, all parts meet performance requirements, but rejects can occur at the edges since material and machine capability are not perfect. Other controllable parameters can be added to target for improved quality, such as melt temperatures (in the plasticator, nozzle, and in the cavity) and rate of injection. See **computer processing control automation; fabricating time; molding volume diagram; process control; processing window.**

molding, autoclave See **autoclave molding operation; autoclave thermal expansion molding; molding, thermal expansion.**

molding, back See **injection molding, back-molding.**

molding, bag See **reinforced plastic-bag molding.**

molding basics See **World of Plastics Reviews: Basics and Overviews of Fabricating Processes.**

molding, carousel style See **clamping platen, rotary.**

molding centrifugal See **casting, centrifugal.**

molding certification See **processor certification.**

molding, clamshell See **thermoforming, clamshell.**

molding, coating in-mold A melt-processable paint coating that forms a skin layer within the mold. See **coating; coating, in-mold decorating, labeling; injection molding, in-mold.**

molding, cold Properly prepared compound is shaped at room temperature in a mold and subsequently cured by heating or baking in an oven. See **bituminous plastic; thermoforming, comoform cold forming/molding.**

molding cold shot See **injection-molding cold shot.**

molding cold slug The first plastic melt that enters an injection-molding machine cold runner mold. It passes through the sprue orifice and is cooled below the effective molding temperature. Usually a well in the runner system is used to unload this cold slug. See **extruder cold shot.**

molding cold slug well The space or cut-out in the runner system (such as opposite the sprue travel of the melt in the mold) that traps the cold slug so that it does not enter the cavity.

molding, computer-integrated See **computer-integrated manufacturing.**

molding, contact See **reinforced plastic molding, contact.**

molding, continuous See **blow molding, extruder (continuous); injection molding, continuous.**

molding, die-slide (DSM) A patented process from Japan Steel Works for injection molding two halves of a hollow part in cavities on opposite sides of a single mold. After the mold opens, a slide plate on the stationary platen aligns the two parts with a second injection joining the parts.

molding, dip See **forming, dip.**

molding, dished A depression in a molded surface.

molding, double-daylight See **injection molding, double-daylight.**

molding, double-shot A method for producing two-color or two different plastics in a part using an injection-molding machine with two plasticators. The part molded first becomes an insert for the second shot. Other processes can be used, such as injection blow molding and compression molding. See **blow molding, injection; coinjection molding.**

molding draft See **mold-cavity draft.**

molding dwell **1.** A pause in pressure just prior to the mold completely closing. See **mold breathing. 2.** The time between when the injection-screw ram action is fully forward holding pressure on the plastic in the cavity and the time the ram action retracts.

molding fiber shrinkage See **reinforced plastic molding fiber shrinkage.**

molding, film-insert (FIM) A cut film that is decorated or labeled, thermoformed to shape, and then inserted in the mold. See **inlay or overlay.**

molding flash line A raised line that is evident on the surface of a molding and formed at the junction of the mold faces such as at the parting line after the removal of the excess flash. It is usually removed by high-speed buffing or grinding. See **mold flash; sanding.**

molding, flow Leatherlike (plastic) materials are made by placing a die-cut plastic blank (usually solid or expanded vinyl with or without a coated substrate) in a mold cavity (usually silicone rubber mold) and applying heat with a high-frequency radio generator. Melted plastic fills up the mold cavity and reproduces the texture in the mold cavity. Modifications to step up production are used, such as a rotating arm with the mold-cavity pattern facing outward and vertical to the arm. See **poromeric plastic; texturizing.**

molding, formed See **forming; thermoforming.**

molding, hand lay up See **molding, open-mold.**

molding holding pressure See **injection molding holding pressure.**

molding hollow part See **molding, die-slide; injection molding.**

molding, hot See **vacuum hot pressing.**

molding, impression See **forging; mold-cavity hobbing.**

molding index See **test, molding index.**

molding, infusion See **reinforced plastic resin transfer molding.**

molding, in-mold See **injection molding, in-mold.**

molding, intermittent See **blow molding, extruder (intermittent); extruder; injection molding.**
molding, isotactic The compressing or pressing of a powder material (plastic, etc.) under a gas or liquid so the pressure is transmitted equally in all directions. Examples include autoclave, sintering, injection-compression molding, elastomeric mold using hydrostatic pressure, and underwater sintering. Also called *isotactic pressing* or *hot isotactic pressing* (HIP). See **injection molding, nonplastic; sintering.**
molding, jet See **injection molding, jet.**
molding, lagging A process that involves the wrapping of plastic-impregnated tape (prepreg) around a cylindrical mandrel and applying pressure on the tape by shrink tape. The prestretched shrink tape Tedlar is the most commonly used; it shrinks on application of heat. Also called *tape laying*. See **tape.**
molding, laminated A molded product that is produced by bonding together layers of plastic-impregnated material (prepreg) using heat and pressure. The layers are often cut to particular shapes prior to being placed in the mold. See **laminate; reinforced plastic prepreg.**
molding lift A complete set of moldings that are produced in a single operation of a press. Output rate may be expressed in terms of number of lifts per hour.
molding loading tray A tray that automatically moves over the cavity and feeds the mold by "dropping" material or inserts into a single or multicavity by the withdrawal of a sliding bottom to the trays. Also called *charging tray*.
molding, low-pressure See **reinforced plastic, low-pressure.**
molding, match-metal See **reinforced plastic molding, match-metal.**
molding material The various types and forms of plastic materials or compounds that are used including pellets, powders, flakes, and liquids. See **plastic material; preheating.**
molding metal See **blow molding metal; injection molding, nonplastic.**
molding, micro- See **injection molding, micro-.**
molding, multilive feed See **injection-molding melt-flow oscillation.**
molding, multimaterial See **clamping platen, rotary; coinjection molding; injection molding, two-shot molding.**
molding, open-mold **1.** Pouring or placing a plastic into a mold cavity with or without a lid and permitting it to cure or polymerize into the solid shape of the cavity. See **casting; reinforced plastic molding, contact; reinforced plastic hand lay-up; rotational molding.**
molding operation See **operation, automatic; operation, manual; operation, secondary; operation, semiautomatic.**
molding, over- See **injection molding, two-shot.**
molding parting film See **reinforced plastic bag molding.**
molding, powder A technique for producing products of varying sizes and shapes with hollow sections. The hot melt is forced against the inside wall of the mold, which is either stationary or rotating. See **casting, slush-molding; powder molding; rotational molding.**
molding pot See **transfer molding.**
molding, prepolymer See **foamed, prepolymer.**
molding, prepreg See **reinforced plastic layup, wet.**
molding pressure **1.** The pressure that is developed by a screw or ram to push melt into a mold cavity. **2.** The pressure that is maintained on the melt after the cavity is filled until the gate freeze-off allows the complete transformation to a solid state. **3.** The pressure that is applied on the material after it fills the closed injection or compression mold cavity.
molding, pressure bag See **reinforced plastic pressure-bag molding.**
molding pressure, contact Molding or laminate unreinforced or usually reinforced thermoset plastic under no or very little pressure—usually less than 10 psi (70kPa)—to obtain the desired shape followed by curing outside the mold. Cure can be either at room temperature using a catalyst-promoter system or in an oven with or without additional pressure. Also called *open molding* or *contact pressure molding*. See **casting; molding, open-mold; reinforced plastic bag molding.**
molding pressure, high In reinforced thermoset plastics, a molding or laminating process in which the pressure used is greater than 200 psi (1,400 kPa) but commonly 1 to 2 psi (7 to 13.8 kPa). See **caul plate; laminate, high-pressure formable.**
molding pressure, low In general plastics processing, molding in the range of pressures around 400 psi (2760 kPa).
molding pressure pad A metallic reinforcing device that is designed to absorb pressure on the land areas of the mold when the mold is closed.
molding pressure, required The unit of pressure that is applied to the molding material in the mold cavity, such as during injection molding. The area is calculated from the projected area taken at right angles under pressure during complete closing of the mold, including areas of runners that solidify. The unit pressure is calculated by dividing the total force applied by this projected area. It is expressed in psi (Pa). To determine pressure required for a specific material, the melt pressure used is based on past experience or the material supplier's guideline. The pressure is multiplied by the projected area and results in the total clamping pressure required. To ensure that proper pressure is applied, a safety factor (SF) of having available another 10% more pressure is recommended. With experience this SF can be reduced or even eliminated. See **injection molding melt cushion; mold-cavity pressure.**
molding process See **fabricating process type.**
molding-process control The melt entering the mold cavity is controlled by melt pressure. Obtaining the desired molding filling target requires providing the required pressure at each gate or valve gate. Types of pressure controls include the injection unit, sequential valve gating, and

independently controlling each valve. See **injection molding process control; mold gate; process control.**

molding, pulp Plastic-impregnated pulp material is preformed, usually by the application of a vacuum, dried, and subsequently molded, usually by compression. See **wood pulp.**

molding, quenched A method of rapidly cooling thermoplastic molded parts as soon as they are removed from the mold. This is generally done by submerging the parts in water.

molding, ram See **injection-molding machine, ram.**

molding, resin transfer See **reinforced plastic, resin-transfer molding.**

molding, rock-and-roll A method that is similar in some respects to rotational molding, except that the mold rotates only on the horizontal axis while the mold ends are rocked up and down. See **rotational molding.**

molding, rotary A type of injection molding, blow molding, or compression molding that utilizes a plurality of mold cavities mounted on a rotating platen or table. This process is not to be confused with rotational molding. Also called *rotary press.* See **clamping platen, rotary.**

molding, rotational See **blow molding, injection-with-rotation; rotational molding.**

molding, rubber See **forming, rubber-pad.**

molding, screw-transfer See **compression molding, screw preplasticator; transfer molding.**

molding, SCRIMP See **reinforced-plastic SCRIMP process.**

molding, shell See **foundry shell molding.**

molding, sheet-molding compound and vacuum-press (VPM) A method that uses vacuum assist to process at a low molding pressures. With a molding compound such as sheet-molding compound that incorporates a physical thickening agent rather than a conventional chemical thickening agent, low clamping pressures of only 100 to 200 psi (0.69 to 1.38 MPa) are used. This type of SMC is called LPSMC. See **reinforced-plastic sheet-molding compound; sheet-molding compound; vacuum press.**

molding, short shot See **short.**

molding shrinkage The difference in dimensions between a plastic molding and the mold cavity in which it was molded, both being at room temperature when measured. It is expressed in./in. (cm/cm). Shrinkage usually occurs in the mold while it is solidifying or curing; however, certain plastics may take up to 24 hours before they have completed shrinkage. In designing a product and its mold, it is important to make allowance for shrinkage. See **design shrinkage; shrinkage.**

molding, slush See **casting, slush-molding; molding, powder; rotational molding.**

molding snap fit See **design, snap-fit.**

molding, solvent A process for forming thermoplastics by dipping a male mold into a solution or by dispersing the plastic and drawing off the solvent, leaving a layer of plastic film adhering to the mold and later removed.

molding, sprayup See **reinforced plastic spray-up.**

molding, squeeze See **reinforced plastic squeeze molding.**

molding, steam See **expandable plastic steam molding.**

molding, structural-web A low pressure foam molding method that applies to the gap between structural foam molding and injection molding. Its surface does not have the usual SF characteristic swirl pattern. It can produce very large, lightweight parts with smooth surfaces like conventional injection-molded parts. See **foam; injection molding, foamed.**

molding suckback See **injection molding screw suckback.**

molding, thermal expansion The process in which elastomeric tooling are constrained within a rigid frame to generate consolidation pressure by thermal expansion while curing in an autoclave and other processes. During curing, the plastic expands. See **autoclave thermal expansion molding.**

molding thread See **molded screw thread.**

molding time Curing time. See **cure; cycle.**

molding, two-color See **injection molding, two-shot.**

molding, two-shell A technique that produces hollow parts by molding (injection, compression, blow molding, rotational molding, etc.) two halves with mating flanges or the equivalent and in turn assembled by different techniques. See **joining-and-bonding method; thermoforming, clamshell; welding.**

molding, two-shot See **injection molding, two-shot.**

molding unscrewing device See **molded screw thread.**

molding, vacuum bag See **reinforced plastic vacuum-bag molding.**

molding volume diagram (MVD) A diagram that can be analyzed to find the best process settings of three combinations evaluated during start-up, such as melt temperature, mold temperature, and injection or ram pressure. See **computer processing control automation; fabricating time; molding area diagram; processing window.**

molding wall thickness See **radioisotope.**

molding weld-line overflow tab A small, localized extension of a part at a weld line junction that allows a longer melt-flow path for the purpose of obtaining a better fusion bond of the meeting melt fronts. See **weld line.**

molding with rotation See **blow molding, injection-with-rotation.**

molding witness line A line on a molded part that is due to poor alignment or fit of metal mating actions, such as sliding cores.

molding XTC See **reinforced plastic, XTC.**

molding, zero-defect Statistical process control and statistical quality control in the injection-molding process has helped processors to achieve zero defects. See **statistical assessment; zero defect.**

mold knife edge A projection from the mold surface that has a narrow included angle. It is undesirable because it is susceptible to breakage under molding pressures.

mold land The area of those faces of a closed mold that come into contact with one another.

mold latch A device that holds together two members of a mold that are usually held together mechanically.

mold-latch plate A removable core that holds insert carrying pins on the upper part of the mold.

mold lay-up See **reinforced-plastic lay-up.**

mold-leader pin and bushing Pins, usually four, maintain the proper alignment of the male plug and female cavity as the mold closes. One of the pins is not symmetrically placed so that the mold halves can be aligned only one way, eliminating misalignment. Hardened steel pins fit closely into hardened steel bushings. Also called *guide pins*.

mold life The number of acceptable parts that can be produced in a particular mold. Molds can run a few hundreds to many millions. Design, construction, and cost of a mold depend on the life time required.

mold loading well The top volume of a cavity that is usually for compression molding bulky compounds. Its size is dependent on the materials bulk factor. See **bulk factor.**

mold locating ring A device that aligns the nozzle of an injection cylinder with the entrance of the mold's sprue bushing. Also called *register ring*.

mold locking ring A slotted plate that locks the parts of a mold together while the material is being injected or placed.

mold, loose-punch The male part of the mold when it functions in such a way that it remains attached to the molding when the press opens and molding is removed. It is commonly used for moldings that possess threads or undercuts, when the punch cannot be removed from the molding merely by opening the press.

mold lubricant A substance that is applied on or into molds to eliminate or reduce friction or prevent adhesion of its component parts. See **butyl stearate; lubricant.**

mold maintenance A mold usually represents an important and costly part of the production line. Any protruding parts should be protected against damage in transfer. The mold surfaces, especially cavities and cores, should be covered with a protective, easy-to-remove coating against surface corrosion when the mold is not operating. For special protection, vacuum containers are used after the mold is properly dried. Records should be kept to ensure that required maintenance is accomplished on a regular schedule. See **maintenance, preventive; troubleshooting.**

moldmaker directory The SPI issues the directory.

moldmaking See **electrical-discharge machine; machining; prototype; tooling.**

mold, male See **mold cavity, male.**

mold manifold A runner system in a mold that has its own heating or cooling insulated section to control the melt and be ready for injection into the cavity. See **mold runner.**

mold material Molds are constructed of various materials, including different grades of steels; beryllium copper alloy, brass, aluminum, kirksite, sintered metal, steel-filled epoxy plastic, and flexible plastic. The most commonly used is P20 steel, a high grade of forged tool steel that is relatively free of defects and is a prehardened steel. It can be textured or polished to almost any desired finish and is a tough mold material. H-13 is the next most popular mold steel used. Stainless steel, such as 420 SS, is the best choice for optimum polishing and corrosion resistance. Other steels and materials are used to meet specific requirements, such as copper alloys for fast cooling. See **aluminum; automobile, composite; beryllium copper; brass; bronze; chrome plating; die material; electroforming; hardening, case; iron; kirksite; machining; metal; plaster of Paris; photoetching tool; thermoforming mold; tooling, coat; zinc.**

mold material, carbonizing A low-carbon steel surface hardening process that resists wear and abrasion. It is used in molds, dies, and other machine parts. The steel is heat treated in a box that is packed with carbonizing material, such as wood charcoal, heated to 2,000°F (1,093°C) for several hours, and allowed to cool slowly.

mold material, silicone See **adhesive, room-temperature cure.**

mold material, sprayed-metal Molds made by spraying molten metal onto a master until a shell of predetermined thickness is obtained. The shell is then removed and backed with plaster, cement, casting plastic, or reinforced plastic. Its use includes as a mold for thermoforming. See **thermoforming.**

mold melt flow analysis See **injection molding process control; melt-flow analysis.**

mold modeling See **prototyping modeling mold.**

mold, multicavity A mold that has two or more cavities to mold two or more parts. See **compression molding charging tray.**

mold, multi-impression A mold that has two or more cavities.

mold multiple See **blow molding, extruder-mold multiple, siamese.**

mold parallel to draw The axis of the cored position (hole) or insert that is parallel to the up-and-down movement of the mold as it opens and closes.

mold parting agent See **mold release agent.**

mold-parting line A line that is established on a three-dimensional model from which a mold is to be prepared that indicates where the mold is to be split into two halves (sections) by representing where they meet on closing. Also called *cutoff* or *spew*. See **blow molding, extruder-mold; die-parting line; injection molding process-control parting line; mold half.**

mold parting-line sensor An instrument that monitors relative movements of the mold halves in response to plastic melt pressure. See **sensor.**

mold patent See **legal matter: mold contractional obligation.**

mold pattern See **modeling; plaster of Paris.**

mold, perforated See **expandable plastic steam molding.**

mold pillar support The construction of a mold base usually incorporates an ejection housing. If the span in the housing is long, the forces during molding can cause a sizable deflection in the plates that are supported by the ejector housing which in turn causes flashing. To overcome this problem, pillar supports are included so that deflection does not occur.

mold pin Various pins, including dowel pin, ejector pin, leader pin, return pin, side draw pin, and sprue draw pin. See **mold dowel bushing.**

mold pinch-off See **blow molding, extruder, pinch-off.**

mold, polishing See **surface finish; surface treatment.**

mold, porous A material that is made of bonded or fused aggregate (powdered metal, coarse pellets, etc.) that contains numerous open interstices of regular or irregular size that allow air or liquid to pass through the mass of the mold. It is used in different processes, particularly in thermoforming. See **porous metal; thermoforming mold.**

mold, portable See **mold, hand.**

mold, positive A compression mold that is designed to have total applied pressure on the part being molded, the thickness of the part being determined by the amount of charge. The mold is designed to trap all the molding material when it closes.

mold pot **1.** To embed a component or assembly in liquid plastic using a shell, can, or case that remains an integral part of the product after the plastic cures. See **embedding. 2.** A chamber that holds and heats plastic material for transfer to fabricating equipment, such as for injection molding, extrusion, transfer molding, compression molding, and rotational molding.

mold, preengineered Standardized mold components have been available at least since 1943. They provide for exceptional quality control, quick delivery, interchangeability, and lower cost. These available preengineered molds and mold parts provide high-quality manufacturing techniques that result in consistent quality and reduced mold cost. The different manufacturers of these preengineered mold bases and components provide variations that include unique approaches to meeting complex product designs. A major advantage to the molder is saving time and money should a component ever need replacement. Most often these components serve the function of the mold and are not designed for use as plastic-forming mold members.

mold-pressure pad The reinforced hardened steel that is distributed around the dead or open area in the faces of a mold to help the mold land absorb the final pressure of closing without collapsing.

mold-pressure transducer An instrument that is mounted in different parts of a mold (cavity, knock-out pin, etc.) to measure melt pressure. See **transducer, pressure.**

mold protection See **mold maintenance.**

mold-release agent A substance such as silicone, that is put on an interior mold-cavity surface or added to a molding compound to facilitate removal of the molded product from the mold. Using silicone can cause problems if parts are to be decorated in a secondary operation or may interfere with electrical circuits. Also called *parting agent.* See **abherent; additive, surface modifying; butyl stearate; decorating, removing mold-release residue; mold-cavity coating; mold-cavity draft; silicone plastic; wax.**

mold, rotary See **clamping platen, rotary.**

mold, RTV See **adhesive, room-temperature cure.**

mold runner A mold manifold runner system involves all the sprues, runners, and gates through which melt flows from the nozzle of an injection-molding machine (the pot of a transfer molding machine, etc.) through the mold and into the mold cavity. Primary, secondary, and tertiary (sometimes more) runners provide melt flow into one or more cavities. Their diameters are based on the melt-flow requirements of the plastic being processed that are easy to determine. See **injection-molding-machine characteristic; mold manifold.**

mold runner, balanced In a multicavity mold, a runner whose linear distance of the melt flow from the sprue to the cavity gates is the same as that of other runners.

mold runner, cold (for thermoplastic) A mold in which the melt within the mold (sprue to gates) solidifies by the cooling action of the mold, requiring its removal and usually recycling. See **thermoplastic.**

mold runner, cold (for thermoset plastic) Mold in which the melt within the mold (sprue to gates) is cooled in the mold, maintaining its free melt-flowing characteristic so that the next shot starts from the gate rather than the nozzle. The cavity and core plates are heated to solidify the plastic, but the runner system is kept insulated from the cooler manifold section. This action eliminates thermoset scrap that is similar to a hot runner system for thermoplastics. See **thermoset plastic.**

mold runner, hot (for thermoplastic) A mold in which the melt within the mold (sprue to gates) is insulated from the chilled cavity and core. It remains hot, producing no scrap, and the next shot starts from the gate rather than the nozzle.

mold runner, hot (for thermoset plastic) A mold in which the melt within the mold (sprue to gates) is hot as in the cavity and core; all solidify by the heating action. The solid sprue to gate can be recycled at least as filler.

mold runner, insulated A mold that has oversized runner passages like a conventional cold runner system, and is used for certain thermoplastics. The passages in the heated mold-runner system are of sufficient diameter that, under conditions of operation, an insulated surface occurs on the plastic melt runner wall, with hot melt flowing in the center of the runner. The next shot starts from the gate.

mold, runnerless Identifies a thermoplastic hot runner or a thermoset cold runner even though runners are used. See **mold runner cold (for thermoset plastic); mold runner hot (for thermoplastic).**

mold sales See **blow molding market; injection-molding machine sales.**

mold, semipositive A combination of the positive and flash (vertical or horizontal flash) compression molds. It operates as a flash mold until within a short distance of the final closure, when the force plug telescopes within the chase to exert a positive pressure on the charge during the final closing of the mold. See **mold, compression.**

mold shape See **molded part shape, complex.**

mold shear edge The cut-off edge of the mold.

mold, shell See **plastic, foundry.**

mold, shuttle See **clamping platen, shuttle.**

mold, siamese blow See **blow molding, extruder-mold multiple mold, siamese.**

mold side action A mold that operates at an angle to the normal open-closed action, permitting the removal of a part that would not otherwise clear a cavity or core. It may have a pin to core a hole that has to be withdrawn prior to opening the mold. See **mold coring, side.**

mold, silicone See **molding, flow.**

mold, single-impression A mold with only one cavity.

mold, split-ring A mold in which a split-cavity block is assembled in a chase to permit the forming of undercuts in a molded part. These parts are ejected from the mold and then separated from the part. Also called *split mold.* See **mold chase.**

mold sprue A feed opening in a mold that is directing melt into the mold from an injection-molding machine nozzle. Also called *stalk.* See **injection-molding machine locating ring.**

mold sprue bushing A part of the mold that provides an interface between the injection-molding machine nozzle and runner system in the mold.

mold sprue picker A device that removes solidified plastic sprue from an open mold. Also called *sprue puller.*

mold spew groove The groove in a mold that permits the escape of excess or surplus plastics.

mold, stack Rather than handling a single mold with the usual two plates, a third or intermediate movable plate makes possible center or offset gating of each of the cavities on two levels. Thus it is a two-level mold or two sets of cavities stacked one on top of the other for molding more parts per cycle. These molds generally use a hot-runner manifold that is located in the center plate (platen). There are also four-stack molds in use. Also called *three-plate mold.* See **clamping platen, floating.**

mold standard and practice The SPI regularly updates its publication on designing plastic molded parts entitled *Standards and Practices of Plastics Molders.* It is useful to designers, purchasing agents, custom molders and processors. It includes engineering and technical guidelines that are commonly used by molders for injection, compression, and transfer molding processes; lists tolerance specifications for plastic materials in metric and English units; and offers a glossary of terms. It reviews important commercial and administrative practices for purchasers to consider when specifying and purchasing molded parts. These customs of the trade include mold type, safety considerations, maintenance requirements, contract obligations, charges and costs, inspection limitations, storage, disposals, proper packing and shipping, and claims for defects.

mold, steam chest See **expandable plastic steam molding.**

mold stop A device such as steel blocks that separates the compression mold to limit the amount of closure. It governs the thickness of the part. Since the plastic could receive less pressure, the part could contain voids.

mold storage During both short- and long-term storage from hours to months or longer, steel molds must be protected from water and humidity. Unprotected steel can almost immediately begin to corrode, resulting in damaged molds that will require repolishing, regrinding, or repair of at least the surface of the mold, which is costly in both labor and machine downtime. It is most cost-effective to protect the molds. Excellent rust protectants are on the market that operate for different time periods. However, most of these anticorrosion treatments must be completely removed before using the molds. Some may require special cleaners, including toxic solvents. Some operations dry-off the mold and enclose it in an air evacuated container for storage. See **cleaning; desiccator; storage.**

mold stripper-plate A plate that strips a molded part from a cavity with or without air support.

mold surface See **polish; surface finish.**

mold sweating Sweating and moisture condensation on a chilled mold surface, particularly during the summer months. This can lead to corrosion, rust, poor finishes, and inferior-quality parts. In addition, rust on guide pins can cause damage to the mold. Keeping the air in the plant or around the mold dry improves part quality and increases production rate. See **desiccant.**

mold temperature See **pyrometer; temperature measurement.**

mold tray A tray under the mold onto which moldings fall during automatic cycling.

mold undercut A reverse or negative draft, such as a protuberance or indentation in molding of a rigid plastic, that necessitates inserts or a split mold for removal of the part. If a flexible mold can be used, it will provide for the rigid part ejection. A flexible plastic mold with a slight undercut usually can be ejected intact. See **mold back draft.**

mold unit A mold that is designed for quick-changing interchangeable cavities. See **mold cavity.**

mold, unscrewing device See **molded screw thread.**

mold venting See **mold-cavity venting.**

mold venting, water-transfer This technique is based on negative pressure-coolant technology. Mold coolant is pulled by a negative pressure instead of by the more conventional pushing by positive water pressure. This system permits venting into the coolant water via the knockout pins or difficult locations in a cavity (such as long, thin cores) that entrap air during molding. They require that the pin or cavity (through a porous metal media) run through the water line. The coolant does not leak into the cavity because it is under atmospheric pressure. In an emergency it could eliminate water leak in a cracked mold that extends into the water line.

mold water channel A channel through which water circulates to cool the melt in the cavity and extract heat. See **mold cooling; water, magnetic.**

mold well In processes such as transfer or compression molding, the space that is provided to take care of the difference in volume between loose pre-molding material and the same weight of material after molding. See **bulk factor; molding.**

mold yoke In a large single-cavity mold, the entire cavity and core plates usually form the mold cavity. In a smaller and multicavity mold, core and cavity blocks (inserts) are mounted on or in the various plates of the mold base. When various components are mounted in the plates, the plates are called a yoke.

mole An amount of substance of a system that contains as many elementary units as there are atoms of carbon in 0.012 kg of the pure nuclide carbon-12. The elementary unit must be specified and may be an atom, molecule, ion, electron, photon, or even a specified group of units. Symbolized it is a mol. See **carbon; Raoult's law.**

molecular activation See **activation; energy.**

molecular adhesion A particular manifestation of intermolecular forces that causes solids or liquids to adhere to each other. It usually is used with reference to adhesion of two different materials, in contrast to cohesion.

molecular-arrangement structure The size and flexibility of polymer molecules explains how an individual molecule would behave if it were completely isolated from its neighbors. Such a condition is obtainable only in theoretical studies on dilute solutions. In actual practice, molecules always occur in a mass, and the behavior of each individual molecule is greatly affected by its relationship to adjacent molecules in a mass. When they are arranged in completely random, intertwined coils, the plastic is in an amorphous state. When neatly arranged and packed, a crystalline state exists. When molecules are stretched, they are in the stretched state. These states relate to their melt-flow characteristics and temperature behaviors during processing and product in service. See **amorphous plastic; chemical and physical characteristics; crystalline plastic; fastener, nonmechanical; molecular microstructure; molecular structure; orientation; rheology; Staudinger, Hermann; stereoregular, plastic; testing and classification; x-ray microscopy.**

molecular asymmetry A molecular arrangement in which a particular carbon atom is joined to four different groups.

molecular atactic stereoisomerism A chain of molecules in which the position of the side chains or side atoms is more or less random.

molecular atecticity The degree of molecular random location that the side chains exhibit of the backbone chain of the plastic.

molecular attraction A force that pulls molecules toward each other. See **polarity.**

molecular beam See **electrospray mass spectrometry.**

molecular bonding Within the different molecular entanglements, there exists intermolecular bonding that relates to the mechanical and thermal properties of many plastics. These forces, in the order of the weakest to the strongest, include London dispersion force or van der Waals attraction, polarity, hydrogen bonding, orientation and crystallinity, ionic bonding, and permanent primary covalent cross-linking. See **chemical composition and properties of plastic; chemical conjugate; molecular double bond; molecular force; valence; van der Waals force.**

molecular bonding force See **temperature and molecular bonding force.**

molecular branched chain A side chain that is attached to the main original chain.

molecular branched short-chain The dominant form of molecular branching in addition polymers that is usually formed by a "backbiting" transfer reaction and primarily results in different side chains. Such branching results in reduced levels of crystallinity.

molecular chain length A length of stretched linear macromolecule that is most often expressed by the number of identical links.

molecular chain scission The breaking of a molecular bond that causes the loss of a side group or shortening of the overall chain.

molecular chemical reaction See **polymerization.**

molecular cleavage Breakage of covalent bonds.

molecular colligative property A property that is based on the number of molecules present. Certain solution properties are extensively used in molecular-weight characterization.

molecular conductivity The conductivity of a volume of electrolyte containing 1 mole of dissolved substance.

molecular conformation The morphological disposition of a molecule in its environment. Different shapes of polymer molecules result from rotation around single covalent bonds in the polymer chain—for example, the coiling of a macromolecular chain in a poor solvent and the uncoiling in a good solvent.

molecular decomposition The breaking down of a molecule into simpler molecules or atoms. See **decomposition.**

molecular diffusion A process of spontaneous intermixing of different substances that is attributable to molecular motion and tends to produce uniformity of concentrations.

molecular dimer A substance that is formed from two molecules of a monomer.

molecular dispersion force An attractive intermolecular force that arises as a result of temporary dipoles induced in the molecules. Also called *London dispersion force.* See **molecular force.**

molecular dispersion, macro- A liquid mixture in which molecular aggregates form the solid or liquid particles of a phase dispersed into a liquid continuous phase where they are generally visible.

molecular distillation A process by which substances are distilled in high vacuum at the lowest possible temperature and with least damage to their composition.

molecular double bond A type of structure in the molecules of organic compounds in which a pair of valence bonds joins a pair of carbon or other atoms. See **molecular bonding; pi; valence.**

molecular fingerprint See **x-ray spectroscopy.**

molecular flexibility See **molecular properties' affect on product properties; molecular bonding.**

molecular force The London dispersion forces are weak intermolecular forces that are based on transient dipole-dipole interactions.

molecular fractionation The different molecular weights of plastics.

molecular gas A gas that is composed of a single species, such as oxygen, chlorine, or hydrogen.

molecular graphic See **computer-aided molecular graphic.**

molecular heat capacity See **molar heat capacity.**

molecular homologous series A series of organic compounds, each member of which differs from its neighbor by the addition of a $-CH_2-$ group in the molecule. Such a series shows a regular and gradual change of properties as the molecular weight increases.

molecularity In a chemical reaction, the number of molecules that come together and form the activated complex. See **chemical reaction.**

molecular-level electron microscope A technique for the observation of individual polymer molecules by electron microscopy. A very dilute polymer solution is sprayed onto a substrate, the solvent is evaporated, and the specimen is shadowed. Individual molecules may then be observed, their dimensions can be measured utilizing the shadow length, and the molecular weight can be determined.

molecular long-chain branching A form of molecular branching that is found in addition polymers as a result of an internal transfer reaction. It primarily influences the melt-flow properties.

molecular, macro- A substance that consists of macromolecules or of macroions, together with small ions sufficient to balance the charges on the large ones. See **molecule, macro.**

molecular mass The sum of the atomic mass of all atoms in a molecule. In plastics, the molecular masses of individual molecules vary widely and are expressed as averages. The average molecular mass of polymers may be expressed as a number-averaging molecular mass or mass-average molecular map. Molecular mass measurement methods include osmotic pressure, light scattering, and sedimentation equilibrium. See **molecular weight determination; radius of gyration.**

molecular mesh See **aerogel.**

molecular microstructure The possible atomic arrangements within the molecular chains are determined by the polymer production procedures and cannot be modified by further processing. Excessive heat or pressure during product fabrication may produce some degradation and scission of molecules; this is normally negligible. See **molecular arrangement structure.**

molecular mobility See **orientation and mobility.**

molecular motion See **heat.**

molecular nucleation The process of including a new high-polymer molecule in a crystalline phase by the start of a new crystal.

molecular orientation See **coefficient of optical stress; orientation.**

molecular properties' effect on product properties Three molecular properties of density, average molecular weight, and molecular-weight distribution affect most of the mechanical and thermal properties that are essential for processing plastics and obtaining required performance of fabricated parts that range from flexible to rigid. In general, increasing MW will increase properties such as tensile and compressive strengths. See **chemical composition and properties; molecular weight.**

molecular, reaction, uni- An elementary step that involves one reactant molecule.

molecular reactivity See **polymer reactivity.**

molecular sieve A microporous structure that is composed of either crystalline aluminosilicates (which are chemically similar to clays or feldspars and belong to a class of materials known as zeolites) or crystalline aluminophosphates that are derived from mixtures containing an organic amine or quaternary ammonia. Pore size ranges from 5 to 10 A. Its outstanding characteristic is its ability to undergo dehydration with little or no change in crystalline structure. Its many uses include catalyst, blowing agent, and drying of liquids and gases. See **zeolite.**

molecular size Size can be expressed as molecular weight or degree of polymerization (DP), hydrodynamic volume, radius of gyration, or some other measure of molecular dimension. Unlike simple compounds where the molecular weight in the sample is uniform, plastic samples are composed of polymer chains of varying length. Thus, a distribution of molecular weights is present. With copolymers, chemical composition and length of polymer chain often vary. Therefore, in expressing polymer molecular weights various average expressions are used. See **viscosity, K-value.**

molecular solution See **chemical introfier; molecular mass; polarity.**

molecular spectroscopy The production, measurement, and interpretation of molecular spectra. See **spectroscopy.**

molecular structure The arrangement or type of monomeric units in a polymer chain. Many chemical and spectroscopic techniques are available for characterizing primary molecular structure. Other structural information is usually sought as part of the primary molecular description regarding the sequence of monomer units and the type and amount of configurational or geometric isomerism present. That information is obtained using techniques similar to those used for determination of low-molecular-weight organic compounds. However, a critical problem in polymer characterization is that many of these techniques require the analysis be performed in solution. This requirement is sometimes difficult to meet, particularly for very-high-molecular weight or cross-linked polymers, and a number of supplemental approaches are necessary. See **atactic plastic; atomic structure; Avogadro's law; crystal structure; designing with plastic tailor-made models; fiber material, plastic; molecular structure; neutron scattering; optical isomerism; optically active plastic; polarity; radiation-resistant plastic; rheology; spectrometry, mass; stereospecific plastic.**

molecular structure and gene See **design, biotechnology.**

molecular-structure configuration In a linear polymer, which generally has a molecular weight greater than 10,000 and contains 1,000 or more atoms, the carbon atoms are bound to one another by covalent bonds. However, the carbon atoms that are linked with a regular fixed distance from one another do not result in a rigid material. Rotation around the axis of the carbon-carbon bond within the hydrocarbon chain allows the atoms to take up all sorts of positions. This action results in the mobility of the entire polymer molecule, which can assume a variety of configurations. The most probable configuration is the loose tangle. Polymer molecules twist and turn on account of their thermal mobility in a way that does not occur with many other shorter molecules. See **chemical composition and plastic properties; covalent bonding; designing with plastic-chemical models; rheological mechanical spectrometer.**

molecular structure, isotactic A plastic's molecular structure that contains a sequence of regularly spaced asymmetric atoms arranged in like configuration in the plastic chain. See **chemistry, stereo-; isotactic plastic.**

molecular structure, nonpolar In molecular structure, a molecule in which positive and negative electrical charges coincide. Most hydrocarbons, such as polyolefins and polystyrenes, are nonpolar. See **polarity.**

molecular structure, stereoisomer An isomer in which atoms are linked in the same order but differ in their arrangement. See **atom, isomer.**

molecular structure, stereoisomer, trans- A stereoisomer in which atoms or groups of atoms are arranged on opposite sides of a chain of atoms.

molecular structure, tailor-made See **designing with plastic tailor-made models.**

molecular symmetry The geometrical design of a molecule, atom, or ion that cannot be divided into like portions by one or more hypothetical planes.

molecular, ter- An elementary step that involves three reactant molecules. See **chemical reactant.**

molecular volume The volume occupied by 1 mole, which is numerically equal to the molecular weight divided by the density.

molecular weight (MW) The sum of the atomic weights of all the atoms in a molecule. It represents a measure of the chain length for the molecules that make up the polymer. Also called *formula weight.* See **atomic weight; centrifuge, ultra-; designing with plastic tailor-made models; light scattering; molecular properties effect on product properties; molecular-level electron microscope; polymer reactivity; rheology; thermal stability; viscosity, dilute-solution.**

molecular weight and aging Reactivity with oxygen, ozone, moisture, and ultraviolet light sensitization via outdoor weathering or high temperature all become important with aging, particularly with the neat plastics. Different additives are used with different plastics to provide slower aging. Certain plastics will improve with aging based on actual service tests and extensive creep tests, but others have limited endurance. Low-MW materials tend to degrade, and higher MWs become stronger through cross-linking. See **aging; plastic, neat.**

molecular weight and melt flow Adequate molecular weight is a fundamental requirement to meeting desired properties of plastics. With MW differences of incoming material, the molded-part performance can be altered; the more the difference, the more dramatic change occurs in the part. Melt flow rate (MFR) tests are used to detect degradation in molded parts where comparisons, for example, are made of the MFR of pellets to the MFR of parts. MFR has a reciprocal relationship to melt viscosity. This relationship of MW to MFR is an inverse one; as the MFR increases, the MW drops. MW and melt viscosity are also related; as one increases, the other increases. See **melt flow.**

molecular weight and structure See **molecular-structure configuration.**

molecular weight and thermal mechanical properties See **chemical composition and properties of plastic.**

molecular weight, average The sum of the atomic masses of the elements that form the molecule, indicating the relative size of the typical chain length of the polymer molecule. Many techniques are available for its determination. The choice of method is often complicated by limitations of the techniques as well as by the nature of the polymer because most techniques require a sample in solution. See **molecular weight distribution.**

molecular weight centrifugation equilibrium A method for determining the distribution of molecular weights by spinning a solution of the specimen at a speed such that the molecules are not removed from the solvent but are held at a point where the centrifugal force tending to remove them is balanced by the dispersive forces caused by the thermal agitation. See **centrifuge, ultra-.**

molecular-weight characterization See **colligative property.**

molecular-weight determination Most plastics are composed of mixtures of molecules of various sizes. This distribution of molecular weights is caused by the statistical nature of the polymerization process. A complete description of the molecular-weight distribution of a plastic is necessary to understand its physical, rheological, and mechanical properties. See **molecular mass; molecular-weight distribution; rheology.**

molecular-weight distribution (MWD) The amount of component polymers that makes up a polymer. Component polymers is a convenient term that recognizes the fact that all polymeric materials comprise a mixture of different polymers of differing molecular weights. The ratio of the weight average molecular weight to the number average molecular weight gives an indication of the MWD. Average molecular-weight information is useful; however, characterization of the breadth of the distribution is usually more valuable. For example, two plastics may have exactly the same or similar average MWs but very different MWDs. There are several ways to measure MWD, such as fractionation of a polymer with broad MWD into narrower MWD fractions and MWD of the narrow fractions. Size-exclusion chromatography is used for the study of MWD. See **centrifuge, ultra-; chromatography, gel permeation; equilibrium centrifugation; chromatography, gel permeation; melt elasticity; melt fracture; melt-pressure sensitivity; temperature sensitivity; testing and classification.**

molecular weight distribution resinography A method for determining the MWD that involves spinning a solution of the specimen at a speed such that the molecules are not removed from the solvent. See **equilibrium centrifugation; resinography.**

molecular weight, equivalent The molecular weight of a chemical divided by the number of functional groups.

molecular weight measurement See **spectrometer, mass.**

molecular weight processing, high See **detonation.**

molecular weight reduction See **ultrasonic degradation.**

molecular weight, toughness, and temperature With certain plastics, such as polycarbonate, the ductile-to-brittle transition temperature is an important transition. It is the temperature where the plastic suddenly changes to failure mode in an impact test. Room-temperature effects of MW in plastics with different melt-flow rates are relatively small; however, the effect on DBTT is dramatic and causes a shift of 45°F (7°C) in the glass-transition temperature as the viscosity changes from high- to low-viscosity plastic. See **glass transition temperature; toughness; viscosity.**

molecular weight vapor-pressure osometer An instrument that determines molecular weights by the decrease of vapor pressure of a solvent on addition of a soluble sample.

molecular weight versus property The MW of plastics influences their properties. For example, with increasing MW, physical properties increase for abrasion resistance, brittleness, chemical resistance, elongation, hardness, melt viscosity, tensile strength, toughness, and yield strength. Decreases occur for adhesion, melt index, solubility, and solution viscosity.

molecule The smallest particle of a substance that is capable of independent existence while still retaining its chemical properties. It is a group of atoms held together by chemical forces; the atoms in the molecule may be identical (H_2, S_2, etc.) or different (H_2O, CO_2, etc.). A molecule is the smallest unit of matter that can exist by itself. See **atom; Avogadro's law; chemical polymer; complex ion; iso-; polymer chemistry terminology; solid; solution, colloidal; Staudinger, Hermann.**

molecule, activated complex The species that is temporarily formed by reactant molecules in the process of product formation.

molecule alignment Plastics can form by aligning themselves into different connections or shapes providing plastics with different characteristics. See **molecular-arrangement structure; polymer, ladder.**

molecule, aliphatic Organic compounds such as petroleum and propane whose molecules do not have their carbon atoms arranged in a ring structure.

molecule, atactic stereoisomerism A chain of molecules in which the position of the side chains or side atoms are more or less random as contrasted to isotactic. See **molecule, isotactic stereoisomerism.**

molecule, atecticity The degree of random location that the chemical molecular side chains exhibit off the back-bone chain. See **molecular-arrangement structure.**

molecule, bifunctional A molecule with two reaction sites for joining with adjacent molecules.

molecule, branched In the molecular structure of plastics, the side chains attached to the main chain. It contrasts with linear molecules. Also called *side chains.*

molecule cell See **cell unit.**

molecule, chain-folded The conformation of a flexible polymer molecule when present in a crystal. The molecule exists and reenters the same crystal, frequently generating folds. See **melt flow.**

molecule chain length Of a chain molecule, the total length measured from atom to atom along the chain. The term should not be used to indicate the direct distance between the ends of the molecule.

molecule chain-length distribution The length of the stretched linear macromolecule. The number of identical links—that is, the degree of polymerization—usually expresses it.

molecule-chain scission The breaking of a molecule chain as a result of a chemical or photochemical reaction, such as degradation or photolysis.

molecule-chain transfer agent A molecule from which an atom, such as hydrogen, may be readily abstracted by a free radical.

molecule, chromophore A molecule or portion of molecule that can absorb light.

molecule, diamagnetic susceptible A relative measure of the degree to which a molecule or atom is repelled by a magnetic field.

molecule, dimer A substance that is comprised of molecules formed from two molecules of a monomer.

molecule, dipole-dipole force Forces between molecules that have permanent dipole moments.

molecule, dipole, induced A dipole that is induced when an ion or polar molecule approaches a nonpolar molecule.

molecule, dipole moment The product of an electronic charge and a charge separation distance.

molecule, disproportion The termination by chain transfer between macroradicals to produce a saturated and unsaturated plastic molecule; a reaction in which a species undergoes oxidation and reduction simultaneously.

molecule enantiomer An optical active molecule and its mirror image.

molecule, folded-chain The conformation of a flexible polymer molecule when present in a crystal. The molecule exists and reenters the same crystal frequently generating folds.

molecule, impure See **crystallization, secondary.**

molecule, isotactic stereoisomerism A type of polymeric molecular structure that contains a sequence of regularly spaced asymmetric groups arranged in like configuration in a polymer chain. Isotactic and syndiotactic polymers are crystallizable. See **molecule, atactic stereoisomerism.**

molecule, large See **chemical composition and properties of plastic.**

molecule, linear A long chain molecule as distinct from one having many side chains or branches.

molecule, macro- A very large molecule that contains hundreds to thousands of atoms. It is a molecule that has at least 1,000 atoms. Natural substances such as cellulose, proteins, and rubber are classified as macromolecules, as are all synthetic polymers (plastics). See **designing with plastic tailor-made models; molecule, macro-; plastic material type; Staudinger, Hermann.**

molecule mean free path The average distance that a molecule travels between successive collisions with other molecules. See **mean.**

molecule, optical active See **molecule enantiomer.**

molecule photolysis The splitting of a molecule through the action of light. There is decomposition into simpler units as a result of absorbing one or more quanta of radiation.

molecule, polar A molecule in which positive and negative electrical charges are permanently separated, as opposed to nonpolar molecules in which the charges coincide. Polar molecules ionize in solution and impart electrical conductivity. The formation of emulsions and the action of detergents are dependent on this behavior. See **dielectric property; electrical conductivity; emulsion; plastic solvation.**

molecule, polar attraction In molecular structure, a molecule in which positive and negative electrical charges are permanently separated. Polar molecules ionize in solution and impart electrical conductivity to the solution. Water, alcohol, and sulfuric acid are polar molecules; carboxyl and hydroxyl are polar functional groups. See **dielectric property; emulsion; molecular structure, nonpolar; polarity.**

molecule, reactive See **aerogel.**

molecule, root-mean-square end-to-end distance A measure of the average size of a coiled polymer molecule, usually determined by light scattering. See **light scattering.**

molecule separation See **polyacrylamide plastic.**

molecule, stereospecific A specific or definite order of arrangement of molecules in space. This ordered regularity of the molecules in contrast to the branched or random arrangement found in other plastics permits close packing of the molecules and leads to high crystallinity.

molecule, syndiotactic stereoisomerism A plastic molecule in which pendant groups and atoms attached to the main chain are arranged in a symmetrical and recurring fashion relative to it in a single plane.

molecule, telomer A molecule that has terminal groups that are incapable of reacting with additional monomers, under the conditions of the synthesis, to form larger molecules of the same chemical type. Also called *aligomer molecule.*

molecule, tetramer A molecule that is formed by uniting four different simple molecules.

molecule, unimeric A single molecule that is not monomeric, oligomeric, or polymeric, such as saturated hydrocarbons.

molecule volume See **Avogadro's law.**

moment of inertia The sum of the products formed by multiplying the mass (or sometimes the area) of each element of a figure by the square of its distance from a specified line. Also called *rotational inertia.* See **design, EI theory; design, sandwich-construction; inertia; modulus and stiffness; torque-shear stress.**

monitoring The continuing sampling, measuring, recording, or signaling of a material or product.

monitoring, process See **computer monitoring information.**
monochromatic See **radiation, monochromatic.**
monocoque structure See **design monocoque structure.**
monofilament See **filament, mono-.**
monolayer **1.** A single layer of atoms or molecules that is adsorbed on or applied to a surface. **2.** The basic laminate or layered reinforced plastic unit from which cross-plied or other types are constructed. See **laminate; reinforced plastic.**
monomer A low-molecular-weight reactive chemical that consists of molecules that are capable of reacting with like or unlike molecules to form a polymer or plastic. Mer is the smallest repeating structure of a polymer. For additional polymers, this represents the original unpolymerized compound. It is the small molecule that forms the units in the polymer chain. See **acetylene; acrylic acid; chemical composition and properties of plastic; ethyl alcohol, oligomer.**
monomer building block See **Staudinger, Hermann.**
monomeric Pertaining to a monomer.
monomer, isotactic Having the asymmetric carbon atoms of successive monomer units in the same steric configuration. See **polymer, isomeric.**
monomer, reactive A low-molecular-weight monomer that has a solventlike consistency.
monomolecular weight An absorbed film that is 1 molecule thick.
morphology The study of the physical form or structure of a material; the overall physical structure of a bulk polymer. Common units are lamellae, spherulites, and domains. See **amorphous plastic; crystalline plastic; light microscopy; semicrystalline plastic.**
morphology, micro- The shape of structural units whose dimensions are such that they can be observed by electron microscopy but not by optical microscopy.
motion control adjustment See **cut, kerf, and registration.**
motion control, mechanical and electronic See **design, motion-control, mechanical and electronic effects.**
motion-control system (MCS) A method of converting electrical energy to mechanical energy in a series of controlled-motion activities, such as those in fabricating equipment. There are constant-speed, variable-speed, and positioning motion-control systems. Although there are many good tuning methods and self-tuning algorithms available to properly tune a motor, most of them are keyed to specific brands of motion controllers or specific types of operations. A very popular style of gain algorithm in use is the proportional-integral-derivative.

MCSs are typically used to coordinate motion between two or more axes, to coordinate or regulate speeds between axes or other machine members, to stimulate mechanical motions, or to make rapid moves with high acceleration or deceleration rates. This precise control of position, speed, acceleration, and deceleration is typically achieved with a motor, drive, feedback device, motion controller, and control system or programmable logic controller. The motor provides the actual motion. The feedback device provides position information from the motion device to the controller that can close the loop between the motion required and the actual motion made by the motor. The drive turns the command signal from the controller into usable current to drive the motor. The motion controller is responsible for closing the loop to the servo and accepting positioning requests from the control system or PLC.

MCSs are able to provide positioning of a load, speed regulation, and acceleration-rate control of servomotors, stepper motors, or hydraulic actuators. Along with these control variables, motion-control systems must provide axis data back to the controller through networking, synchronization of multiple moving machine members (axes), and processing of discrete or analog inputs or outputs. See **accuracy; analog; automation; control, closed-loop; control drive, optimized; controlled motion; design energy and motion control; design, motion-control, mechanical and electronic effects; drive-system control; electric motor, adjustable-speed-drive; Euler equation; machining; piezoelectric effect; potentiometer; repeatability; servo control; temperature proportional-integral-derivative; tooling.**
motion-control system type The four primary types of motion-control systems are bus-based systems, stand-alone motion controllers, hybrid controllers, and programmable logic controllers. On the horizon are more developments with changes in this important area for the fabricator. The following information provides a guide into the basic systems.

(1) Bus-based systems use generic off-the-shelf hardware components and operating systems. They combine with proprietary custom-developed motion control applications. Typical use includes simple, repeatable motion control. In general, these systems offer lower hardware costs.

(2) Stand-alone motion controllers have the controller, input/output data, operator interface, and communications built into a single package. This integral system allows minimum time and cost for typical machine applications. While the initial hardware cost may be more expensive than bus-based systems, the total application cost may be lower due to decreased software, development, and maintenance investment. However, they do not offer the same flexibility for communications and operators interfaces as a bus-based system and are sometimes difficult to integrate into large-scale processes. Stand-alone systems are often used for highly precise motion control with a specific integrated operator interface, where there is no need for connection to other plant-floor equipment.

(3) Hybrid motion controllers have a motion controller and servo drives controller packaged together and are de-

signed for multiple controller/drive axes. They offer the same advantages as stand-alone systems with a reduced cost for multiple axes. They can also present decreased flexibility with I/O and operator interface as well as handle difficult integration for large-scale processes.

(4) Programmable logic controllers are acceptable for a wide range of motion applications. They are used as a module in the PLC rack. Coarse motion planning along with I/O, operator interface, and communications are integrated into the PLC and communicated into a motion module plugged into the PLC. The motion controller then only needs to close the servo loop. The dedicated motion modules use a separate microprocessor for improved response time. Multiaxis control can be synchronized off a common system clock in the PLC backplane. Because there is a fairly large installed base of PLCs, motion-control integration into large-scale processes can be a low-cost, high-performance option for many fabricators. See **control, closed-loop; servo control.**

motionless mixer See **static mixer.**

motor drive See **electric-motor drive; servo-control-drive reliability.**

mottling See **color, mottle; screw marbleizing.**

muffle furnace A high-temperature furnace that is primarily used to burn off cured plastics.

Mullen effect See **stress softening.**

multicolor See **colorant; injection molding, two-shot.**

multilayer film A thermoplastic film that consists of two or more different or similar films joined together to attain special properties. See **coextrusion; film; laminate.**

multilive feed process See **injection-molding melt-flow oscillation.**

multiple molding See **clamping platen, rotary.**

multiscrew See **extruder, multiple-screw; extruder, twin-screw; extruder, single-screw.**

multishot molding See **injection molding, two-color.**

Mylar A thermoplastic film that is produced from the polyester of ethylene glycol and terephthalic acid. The fiber made by this method is called Dacron. Mylar and Dacron are DuPont trade names.

N

nail As plastics continue to show up in applications originally intended for wood, such as furniture, shoe heels, and building sidings, conventional nails are increasingly used as an assembly device. Polystyrene structural foams used in furniture, for example, have been specially formulated to accept and hold nails. For ABS plastics used in heels, conventional woodworking equipment (nailing machines) has been successfully used to attach the heels to the shoes. The stresses involved and the nail-holding ability of the plastic must be taken into consideration. See **acrylonitrile-butadiene-styrene plastic; load support; stress.**

nanometer (nm) A unit of length that is equal to one billionth (10^{-9}) of a meter. It is often used to denote the wavelength of radiation, especially in the ultraviolet and visible-spectral region.

nanoparticle See **composite, nano-.**

nanosecond One-billionth (10^{-9}) second. Computer data, even log segments, are commonly transmitted in nanoseconds.

nanotechnology The practice and description of microscopic devices. Plastics and its special processing techniques are important in fabricating and advancing certain type devices. See **electronic microminiaturization.**

nap See **fabric nap.**

naphtha A volatile, flammable liquid that is used as a solvent.

naphthotriazolylstilbene See **optical brightener agent.**

National Certification in Plastics See **processor certification.**

National Fire Protection Association See **fire retardance.**

National Institute of Standards and Technology (NIST) An agency of the U.S. Department of Commerce's Technology Administration. NIST's primary mission is to promote U.S. economic growth by working with industry to develop and apply technology, measurements, and standards. Located in Gaithersburg, MD, it was previously called the National Bureau of Standards. See **measurement.**

National Plastics Center and Museum (NPCM) A U.S. plastics center and museum that includes the Plastics Hall of Fame. It is located in the plastics pioneer city of Leominster, MA, which is where the plastics industrial revolution began.

Natta catalyst See **catalyst, Ziegler-Natta.**

natural A substance or mixture that occurs in nature, such as polysaccharide. It is the opposite of a synthetic material, such as practically all plastics. See **organic; organic, in-polysaccharide plastic; synthetic.**

natural plastic A mixture of large molecules of variable sizes that results from a natural polymerization (rubber) or polycondensation (gum, lacquer). See **polyhydroxybutyrate plastic.**

neck-in The localized reduction in cross-section that usually occurs in a material under tensile or compression stress. During fabrication of products, necking occurs, such as when the width of extrudate film leaving the die is necked-in as it moves downstream. Also called *neck-down* or *necking.* See **design sealant joint shape; extruder neck-in and beading; extruder pipe and tubing; tensile analysis; tensile stress necking.**

needle blow pin See **blow molding, extruder blow-action.**

neodymium boron iron See **plastic, magnetic.**

neoprene elastomer A generic name for synthetic rubbers that are made from polymers of chloroprene and are noted for their good resistance to oil, solvents, heat, sunlight, ozone, and weathering. Most types may be vulcanized to tough products without the use of sulfur. Also called *polychloroprene* or *chloroprene rubber.*

Chloroprene rubber (CR) is perhaps the most natural rubberlike of all synthetic plastics or elastomers, particularly with regard to its dynamic response. CRs are a family of elastomers with a property profile that approaches that of natural rubber (NR) but that has better resistance to oils, ozone, oxidation, flame, aging, and heat. CRs are about 25% heavier than NR and do not have the low temperature flexibility of NRs. See **dynamic; elongation; polychloroprene rubber/elastomer; rubber.**

Neoprene rubber processing considerations usually start with the choice of the grade of neoprene, and frequently two or more grades are used to obtain the proper combination of processing and vulcanizate properties. All types can be mixed in internal mixers or mill mixed. When the mix is completed, the batch is dropped on a sheet-off mill, quickly cooled, and prepared for storage. Compounds can be extruded using either cold-feed (long-barrel) or warm-feed (short-barrel) equipment, calendered, and vulcanized in batch processes like press and steam autoclave or continuous operations like a continuous-vulcanization steam tunnel, hot-air oven, microwave, and liquid-curing-medium equipment. See **extruder, liquid-curing-medium process; extruder wire and cable process, continuous-vulcanization; litharge; mixer.**

nest See **fixture.**

nested fabric See **reinforced-plastic nesting.**

netting analysis See **filament winding netting analysis.**

network See **intelligence, natural.**

neutron An uncharged elementary particle that has a mass nearly equal to that of the proton. It is present in all known atoms except the hydrogen nucleus. See **radiation activation.**

neutron scattering Small-angle neutron scattering (SANS) that gives information related to the average molecular structure. It has been used in numerous applications, such as the fields of polymer science, physical chemistry, materials science, and colloidal. See **electromagnetic radiation; molecular structure.**

newspaper, recycling See **paper; recycling commingled plastic; waste.**

Newton The force that, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 meter per second squared (kg m/s^2). This is the SI unit of force.

Newtonian flow See **viscosity, Newtonian flow.**

Newtonian viscosity An alternate name for *coefficient of viscosity*. See **viscosity, Newton's law.**

nickel (Ni) A malleable, silvery metal that is readily fabricated by hot or cold working, takes high polish, and has excellent resistance to corrosion. It is used in electroplated protective coatings and electroformed coatings on plastics. From a structural standpoint, some Ni alloys are among the toughest known materials. See **coating, electrodeposition; screw coating.**

night-to-day light switching See **plastic, light-switchable.**

nip The radial distance or V that is formed between rolls such as a calender, extruder, or mill on a line of centers. In-going safety devices in the nip areas are built into these machines. They protect the hands of operators. An emergency stop device is placed in an accessible location on the upstream side. If a problem develops, the machines immediately stop. See **calendering, control nip pressure; calendering safety; extruder roll; safety.**

nip distance The radial clearance between rolls.

nitrate plastic See **cellulose nitrate plastic.**

nitration The introduction of the nitro group (NO_2) into an organic compound.

nitriding A process that is commonly used on screws, barrels, and valves to create hard wear resistant surfaces to a slightly greater and more uniform depth than gas nitriding with less distortion or contamination of the workpiece. In this process of surface hardening, certain alloy steels are heated to about 315°C (600°F) in an atmosphere of hydrogen gas, adding an electrical charge to the nitrogen and steel and allowing a bombardment of the positively charged steel by hydrogen and nitrogen atoms. See **barrel composition; screw coating.**

nitrile rubber (NBR) A synthetic rubber that is made by random polymerization of acrylonitrile with butadiene by free radical catalysis. The copolymers vary basically in butadiene-acrylonitrile ratios, Mooney viscosities, and staining properties. They have low temperature resistance and are resistant to oils, solvents, greases, heat, and abrasion. They are used in oil-resistant applications, shoe soles, gaskets, fuel hose, packing oil seals, hydraulic equipment, and adhesives. Also called *acrylonitrile elastomer* or *butadiene rubber*. See **test, Mooney viscosity.**

nitrile rubber, hydrogenated elastomer (H-NBR) A synthetic rubber that has considerably better heat resistance than NBR, some reduced swelling resistance, and more resistance to chemicals and ozone. It is cross-linked by the peroxide process.

nitrile-silicone elastomer (NSR) A rubber that combines the characteristic properties of silicones with the oil resistance of nitrile rubber and provides improved solvent resistance.

nitrocellulose plastic See **lacquer.**

nitrogen (N_2) A diatomic gas that is colorless, odorless, noncorrosive, nonflammable, nondiscoloring of plastic, and tasteless that constitutes about four-fifths of earth's air. Its uses industrially are extremely diverse, including the production of nitric acid and ammonia, which are important raw materials in the manufacture of plastics. See **ammonia; autoclave nitrogen atmosphere; devolatization; polishing, cold-gas.** Gas or liquid N_2 is used in different processes (blow molding, gas-assist injection molding, foam molding, etc.) and competes with other cooling gases or liquids (oxygen, carbon dioxide, water, etc.). It is available in cylinders or produced using an in-plant system when quantity requirements exist, to reduce cost to at least half. The membrane system includes a compressor and storage cylinder bank. A compressor/controller provides gas-pressure adjustments such as from 70 to 3,000 psi (½ to 21 MPa). See **blow molding; foam and blowing agent; injection molding, gas-assist.**

nitrogen autoclave curing See **autoclave nitrogen atmosphere.**

nitrogen cured See **cross-linking, radiation; extruder wire and cable cross-linking PE with peroxide; extruder wire and cable process, dry cure.**

nitrogen liquid See **deflashing, cryogenic; recycling, cryogenic.**

noble gas core The particularly stable electron configurations of noble gases (ns^2 for helium and ns^2 np^6 for other noble gases). See **krypton.**

noise **1.** In flaw detection, an undesired response to dimensional and physical variables in the test piece that is called *part noise*. **2.** Any undesired signal, acoustic or electrical, that interferes with normal reception, such as processing. Noise interference is often misunderstood or misdiagnosed because it seems mysterious and complex, but the problem is easy to solve by following well-known and proven procedures. For example, noise problems caused by electrical interference are usually traceable to inadequate or insufficient electromagnetic protection in the readout instrument and poor grounding. See **sensor, noise-effect. 3.** The intensity, or loudness, of sound is measured on a logarithmic scale in units of dB (decibel). The human ear does not respond equally to sounds of different frequencies. Typical dB noise levels are 140 threshold pain, 118 jet aircraft at 500 ft (150 m), 112 unmuffled motorcycle, 104 loud lawnmower, 100 rock 'n' roll band, 95 subway train at 20 ft (6 m), 82 heavy traffic at 25 to 50 ft (8 to 15 m), 72 vacuum cleaner, 66 dishwasher, 60 conversational speech at 3 ft (1 m), 50 business office, and 42 home.

nonaxisymmetric blow molding See **blow molding, extruder, three-dimensional.**

nonchromatic light See **photoelasticity.**

nonconductive See **plastic conductivity.**

noncrystalline plastic See **amorphous plastic.**

nondestructive inspection See **test, nondestructive acoustic-holography.**

nondestructive testing A test that does not change or destroy a part. Destructive tests are often performed to determine how much abuse the part can tolerate without failing, thus ultimately resulting in a nondestructive test. See **testing; test, nondestructive.**

nondestructive test, proof load Any loading that is less than that required for ultimately breaking down the material.

nondurable goods Products with a relatively short useful life, such as newspapers or disposable packaging. See **durable goods.**

nonelectrolyte A substance that gives a solution that is not electrically conducting when it is dissolved in water or some other polar solvent. See **electrolyte.**

nonene See **propylene tetramer.**

nonflammable material A solid, liquid, or gas that does not burn under normal conditions. See **combustible.**

nonhygroscopic See **drying operation, nonhygroscopic plastic.**

nonionic See **emulsifying agent.**

nonisotropic See **directional property, isotropic, non-.**

nonlaminar flow See **melt flow, nonlaminar.**

nonlinear function See **linearization.**

non-Newtonian flow See **viscosity, non-Newtonian flow.**

nonplastic molding See **injection molding, nonplastic.**

nonpolar See **molecular structure, nonpolar.**

nonresonant forced vibration technique A technique for performing dynamic mechanical measurements in which the sample is oscillated mechanically at a fixed frequency. Storage modulus and damping are calculated from the applied strain and the resultant stress and shift in phase angle. See **damping; dynamic mechanical measurement; resonant forced vibration; vibration.**

nonreturn valve See **screw tip, injection.**

nonshrink concrete See **plastic-concrete composite.**

nontoxic Not poisonous. See **toxicity.**

nonwoven See **fabric, nonwoven.**

Noryl GE Plastics' tradename for its family of polyphenylene oxide plastics.

notch effect The effect of the presence of specimen notch or its geometry on the outcome of a test, such as an Izod impact strength test. Notching results in local stresses and accelerates failure in both static and cycling testing (mechanical, ozone, cracking, etc.). See **test, impact.**

notch sensitive Breakable when scratched, cracked, or notched. In general, low notch sensitivity is associated with ductile materials, and high notch sensitivity with brittle material. See **test, impact notch-factor.**

novolak plastic A thermoplastic phenolaldehyde plastic that in the presence of a cross-linking agent reacts to form a thermoset phenolic plastic. It is characterized by the absence of reactive methylol groups in the molecule, which makes them incapable of condensing with other novolak molecules on heating without the addition of hardeners. See **resole plastic.**

nozzle The hollow-cored metal that is screwed into the end of a plasticating barrel or mixing device and that directs a melt or mix into a device such as a mold cavity. See **blow molding, injection; injection molding nozzle-dispersion disc mixer; injection molding nozzle-plate dispersion plug; injection molding nozzle-pressure control; sonic nozzle.**

nuclear disintegration See **radioactive.**

nuclear gauge See **sensor, nuclear.**

nucleating agent An additive, often crystalline, that is usually added to a crystallizing polymer to increase its rate of solidification during processing. See **transparency, improvement.**

nucleating agent, cell-control An agent that promotes symmetrical, cohesive expansion of cells within foamed polyurethane and polystyrene plastics and to a limited extent in polyethylene and polypropylene plastics. See **foamed cell.**

nucleation, heterogeneous In the crystallization of polymers, the growth of crystals on vessel surfaces, dust, or added nucleating agents. See **equilibrium, heterogeneous; mixture, heterogeneous; plastic material, heterogeneous.**

nucleation/nucleator **1.** With polymers, any foreign additive that assists or acts as a starting site for crystallinity within the plastic. These initiators can reduce cycle time by speeding up the crystalline formations. **2.** The addition of a gas, such as nitrogen, to the polyol in many small bubbles to assist in forming better cell structures during reaction injection molding.

nucleation, primary The mechanism by which crystallization is initiated, often by an added nucleation agent.

nucleation, row See **fiber processing, spinning.**

nucleation, secondary The mechanism by which crystals grow. See **crystal growth habit.**

nucleus The central core of an atom. Although the nucleus occupies only a tiny fraction of an atom, it contains all the mass. Protons and neutrons are present in the nucleus. See **proton.**

number marker The recommended U.S. decimal marker is a dot on the line. When writing numbers less than one, a zero should be written before the decimal marker. Outside the United States the comma may be used for a decimal marker. Recommended international practice calls for separating the digits in groups of three, counting from the decimal point toward the left and right and using a space to separate the groups; space is recommended to be the width of the letter I. In numbers of four digits the space is usually not needed except for uniformity in tables—for example, 9 876 543. and 95 432. and 9876 and 98. and 0.12 and 0.1234 and 0.123 45 and 0.123 456 7 and so on. See **decimal number system; meter, SI.**

numerical control (NC) Prerecorded information or programs that provide instructions for the automatic computer control of machine tools and other operations throughout the plastics (and other) industries. See **auxiliary equipment; computer software.**

nylon plastic A group of crystalline thermoplastics that is mostly aliphatic polyamides prepared usually either by polymerization of dicarboxylic acid with diamine, polymerization of amino acid, or ring-opening polymerization of lactam. They have good resistance to solvents/bases/oils, good surface lubricity, impact, abrasion, creep, high tensile strength and barrier properties with a low coefficient of friction. The different nylons, such as nylons 6/6, 6/10, and 6/12, provide different properties and processing characteristics. They are used in auto parts, electrical and electronic devices such as plugs, gears, pumps, appliance and power tool housings, wire and cable jacketing, pipes, films, and fibers. Also called *PA* or *polyamide.* See **adhesive, iodine treatment; canopy; grass, synthetic; polycaprolactam plastic.**

Various types of nylons provide different properties. For example, nylon 6 has good wettability. Nylon 11 includes high dimensional stability and relatively low melting point, allowing ease of coating and rotational molding. Nylon 12 has the lowest water absorption and specific gravity among nylons. Nylon 66 has good mechanical properties up to 150°C (300°F), and moisture acts as a plasticizer. Nylon 610 tends to retain stiffness and mechanical properties when wet. Nylon 612 retains physical and mechanical properties through a wide humidity range. Its high strength and toughness characterize nylon 66 with good abrasion and fatigue resistance. See **nylon plastic, amorphous; polyamide-imide plastic; polycaprolactam plastic.**

nylon plastic, amorphous An exception for crystalline nylons (PAs) is amorphous PAs that are transparent. Thermoplastic amorphous nylons can be made by rapid quenching of the usual crystalline nylons in the melt stage or by chemical modifications. These nylons are transparent. See **transparency, improving.**

nylon plastic nucleation It is possible to increase crystallinity by nucleation. The result is increased tensile strength, flexural modulus, hardness and creep resistance, decreased elongation, impact strength, and setup time during processing.

nylon plastic recycled See **recycled carpet.**

nylon plastic, transparent See **nylon plastic, amorphous.**

O

octet rule See **chemical octet rule.**

odor A property of many substances that is manifested by a physiological sensation due to contact of the substance's molecules with the human olfactory nervous system. Odor and flavor are closely related, and both are profoundly affected by submicrogram amounts of volatile compounds. Many compounds have a characteristic odor that is an effective means of identification. See **alumina, activated; automotive interior, low-emission plastic; test, organoleptic; waste rasp.**

odorant agent An additive that may be incorporated into a plastic to give a product specific odors (odorant or fragrance agent) or to control or mask an objectionable odor (deodorant or sanitizer agent). Sanitizers may have an antimicrobial role. See **antimicrobial agent; deodorant additive; fragrance concentrate.**

ohm See **insulation resistance.**

oil A wide range of substances that are quite different in chemical nature and result in different physical characteristics. About 90wt% is used for fuel. Also called *petroleum* or *crude oil*. See **feedstock; oil, cracking; oil, crude; oil resources, limited; petrochemicals; plastic material refining; waste, refuse-derived fuel.**

oil and gas Two of the most important natural resources in use throughout the world, which satisfy more than two-thirds of the world's energy demand. Both are important feedstocks for the chemical and plastic industries; about 2 to 3% is consumed for plastics. See **coal; energy consumption; feedstock; gas; hydrocarbon; ore; petrochemicals; plastic products, raw material.**

oil canning The property of a panel that flexes past a theoretical equilibrium point and then returns to the original position. This motion is analogous to the bottom of a metal oilcan when pressed and released. Part flexing can cause stress, fracturing, or undesirable melting of thin-sectioned, flat parts. See **blow molding, extruder, flat-surface.**

oil consumption See **energy consumption.**

oil, cracking A process of decomposing, by heat, the heavy petroleum fractions to obtain lower-boiling materials, such as petrol. Many of the raw materials that are used in the manufacture of plastics are obtained this way. See **cracking; feedstock; fluid-bed process; oil and gas; plastic products, raw material to.**

oil, crude A viscous dark-colored fluid that is found in the earth's crust worldwide and is often accompanied by natural gas and salt water. Oil is a complex and valuable mixture of a range of hydrocarbons. See **gas; hydrocarbon.**

oil, pine See **tall.**

oil-reactive plastic A plastic, used in paints and varnishes, which reacts chemically with a drying oil during the process of solution.

oil resistance The ability of a material to withstand contact with an oil without deterioration of properties or geometrical change to a degree that impairs part performance. Different conditions of exposure can exist, such as temperature, complete immersion, or partial immersion with air.

oil soluble plastic See **paint, oil-reactive plastic.**

oil resources, limited In 1885, a U.S. government official in Pennsylvania (where oil was discovered 30 years earlier) claimed that "oil was a temporary and vanishing phenomenon, one which young men will live to see come to its natural end." In 1919, a U.S. government official stated that "within the next two to five years, the U.S. oil fields would reach their maximum production." Experts in the 1940s again cautioned that the end of U.S. production was in sight. And during the energy crisis of the 1970s, many of the rationales for government controls were based on the premise that no new supplies of oil and natural gas were to be found. Events have proved these predictions wrong, and new technology developments have allowed production to continue. See **steel resources, limited.**

oil, stand A drying oil that has been thickened by heating in an inert atmosphere and without the addition of dryers.

oil wells, undersea Underwater equipment as deep as 330 m (1,080 ft), such as oil wells and pipelines, must be protected against damage due to corrosion, the impact of up to 7,400 ft-lb (10kJ) of falling debris from offshore platforms or supply ships, and cold temperatures, which lead to environmental and economic loss. Protection is achieved with reinforced-plastic sandwich covers using glass-fabric, isopolyester-plastic layers with a PVC foam core. They range in size from 11 m length × 12 m wide × 6 m high (36 × 39.4 × 19.7 ft) to an interconnected cover system that is 850 m (2,790 ft) long. These RP covers replaced the formerly conventional steel and concrete covers. The Norwegian engineering firm ABB Offshore Technology reports that the higher cost of RP is offset by significant savings in shipment due to factors such as lighter weight (by at least 40%), easier installation, easier maintenance, and much longer life (RP does not corrode). See **reinforced plastic.**

olefin See **polyolefin plastic.**

olefinic polymerization See **polymerization, addition.**

olefinic TPE See **elastomer; thermoplastic elastomer.**

olefin plastic See **polyolefin plastic.**
olefin-styrene-acrylonitrile plastic (OSA) A SAN polyalloy with an olefinic thermoplastic elastomer.
oleophilic A substance that likes oil or is wettable with oils.
oleo plastic A semisolid mixture of plastic and essential oil of an agricultural plant and sometimes referred to as balsam. The group consists of drying oils and natural or synthetic plastics. See **balsam plastic.**
oligomer A plastic that consists of only a few monomer units, such as dimer, trimer, or tetramer or their mixtures. See **thermoflow plastic.**
one-shot molding See **foamed, one-shot system.**
one-stage plastic See **resole plastic.**
opalescence The limited clarity of vision through a sheet of transparent plastic at any angle because of diffusion within or on the surface of the plastic.
opaque A material that will not transmit light and is not transparent. Materials that are neither opaque nor transparent are sometimes described as semiopaque but are more properly classified as translucent.
open cell See **foamed cell, open.**
open-loop control See **injection molding process-control optimized; control, open-loop; process control.**
open system A system that can exchange both mass and energy with its surrounding.
operation, automatic A machine that operates automatically to perform a complete in-line extrusion operation or molding cycle where programmed functions repeat. It stops only in the event of a malfunction or if it is manually interrupted. See **automation; fabricating process.**
operation, manual An operation in which each function and the timing of each function is controlled manually by an operator.
operation, primary The main equipment that is used to fabricate products, such as the blow-molding machine, extruder, or injection-molding machine.
operation, secondary After fabricating (primary) products, secondary operations may be required to produce the final finished product. These operations can occur in-line or off-line. They include any one or a combination of operations such as the following: annealing (to relieve or remove residual stresses and strains), postcuring (to improve performance), plating, joining and assembling (adhesive, ultrasonic welding, vibration welding, heat welding, etc.), drilling, cutting, finishing, polishing, labeling, and decorating/printing. The type of operation to be used depends on the type of plastic used. For example, with decorating or bonding certain plastics can be easily handled while others require special surface treatments to produce acceptable products. See **auxiliary equipment; processor certification; product, semifinished; tumbling.**
operation, semiautomatic Performing a complete cycle of programmed molding functions automatically and then requiring an operator to manually start another cycle.
operator's station The position where an operator normally stands to operate or observe the machine. See **machine reach point.**
optical analysis See **light schlieren system; stress analysis; test, microtoming optical-analysis; test, nondestructive photoelastic stress-analysis.**
optical, bottle sorter See **bottle sorter, optical; recycling, automatic-sorting; sensor, inductive and capacitive proximity; sensor, nuclear.**
optical brightener agent One of a special class of essentially colorless fluorescent organic substances that absorb ultraviolet radiation above 3,000 A and emit this as visible radiation below 5,500 A. Brighteners are useful in correcting discoloration and enhancing whiteness and brightness, particularly in plastics. For such purposes, the absorption and emission properties are designed to account for the properties of the human visual system, the spectral properties of sunlight, and the nature of the discoloration. Unlike bluing agents, which act by removing yellow light, optical brighteners absorb the visible UV rays and correct their energy into visible blue-violet light. They are used to increase the luminance factor of a white material. They cannot be used in materials that also contain UV-absorbing agents. They are used in PVC sheet and film, fluorescent lighting fixtures, vinyl flooring, nylon fishing lines, and polyethylene bottles. Examples of agents include coumarins, naphthotriazolylstibenes, and benzimidazolyls. Also called *brightener, whitener, fluorescent whitener, colorless dye,* or *optical bleach.* See **bluing agent; fluorescent; luminance; pigment, fluorescent; ultraviolet absorber.**
optical character recognition (OCR) Using optical means to identify graphic characters. See **design, graphic; graphic character.**
optical comparator An inspection machine that uses optics to compare the outline of a part to its required dimensions on a graphic or computer screen. See **computer batch processing; control drive, optimized; controller; device, smart; motion-control system; process control; processing, intelligent; quality-system regulation; rheometer.**
optical conjugate plane Two planes of an optical system such that one is the image of the other.
optical data storage See **computer optical data storage.**
optical density A measure of image intensity by reluctance densitometer based on logarithm to the base of 10 reciprocal of transmittance. See **density; logarithm; quality indicator, image.**
optical distortion See **distortion; wave.**
optical distortion value The minimum distance in inches (cm) between the specimen and screen at which a nonuniform image is produced.
optical fiber See **extruder wire coating, optical-fiber; fiber optic.**

optical image spectroscopy A method of characterizing most of the metallic ions, in addition to certain nonmetals, in terms of the emission spectra produced when electrons are excited by an arc or by other means.

optical isomerism A form of isomerism in which two molecules differ only in their geometry. See **atom, asymmetric carbon; atom, isomer; molecular structure.**

optical light scattering See **atom, isomer; light scattering; molecular structure.**

optically active plastic Only those molecules in a plastic with no symmetric or spiral structures, those without inversion and reflection-symmetry elements, possess optical activity. Both low-molecular-weight compounds and macromolecules must obey the same symmetry rules, and the preparation of optically active plastics present problems similar to those encountered in traditional organic chemistry. Optical activity is used as an analytical tool to relate molecular structures to optical properties. See **plastic properties.**

optically isotropic See **birefringence.**

optically reflective film See **extruder-blown film die, coextruded-reflective.**

optical memory See **photochemical hole-burning spectroscopy.**

optical microscopy See **chemistry, analytical.**

optical monitoring A method of measuring different products such as blown-film bubble diameter, film thickness, and molded dimension. See **die, film and sheet thickness.**

optical property The effects of a material or medium on light or other electromagnetic radiation that passes through it, such as absorption or reflection. See **lens centering; light index of refraction; light transmission; molecule enantiomer; opalescence; transmittance of light; transparent; wave.**

optical sheet, troubleshooting See **troubleshooting optical sheet.**

optical vibration See **wave.**

optimization goal See **design, optimized; quality optimization goal.**

orange peel **1.** A blemish on a finished molded product that is an undesirable, uneven surface resembling orange peel. (Sometimes melt fracture is erroneously referred to as orange peel.) It is usually caused by moisture in the mold cavity that can be removed. For example, during injection molding the problem can be eliminated by changing control settings such as using a faster fill rate, increasing first-stage pressure, increasing sprue or gate opening, or increasing temperature. **2.** An uneven leveling of coating on reinforced-plastic surfaces, usually because of high-viscosity plastic melts. Adding a high-boiling-point solvent to the coating for a wetter surface is helpful, particularly when spraying. **3.** A roughened film surface that is caused by too rapid drying. See **applesauce surface; defect; reinforced plastic; surface finish.**

order, blanket See **purchase order, blanket.**

order, hold See **purchase order hold.**

order of magnitude See **value, order of magnitude.**

ore An aggregate of valuable minerals and gangue from which one or more metals can be extracted at a profit and used in different industries including plastic (fillers, additives, plastic chemical compositions, etc.). See **feedstock; oil and gas; tailing.**

organic Referring to the chemistry of carbon compounds or to a chemical substance that is based on carbon and its derivatives or to a material originating in plant or animal life or for chemicals composed of hydrocarbon origin, either natural or synthetic. See **chemical composition and properties of plastic; chemistry, organic; ether; gum; natural; organic, in-; plastic; synthetic.**

organic compound See **atom; atom, alpha; compound, organic.**

organic, in- Pertaining to or composed of chemical compounds that do not contain carbon as the principal element, except carbonates, cyanides, and cyanates—that is, material other than plant or animal.

organic loss See **ignition loss.**

organoleptic See **test, organoleptic.**

organometallic stabilizer See **deodorant additive; stabilizer.**

organosol A suspension of a finely divided vinyl plastic in a plasticizer (diluent) together with a volatile organic liquid. The plastic does not dissolve appreciably in the liquid at room temperature but does at elevated temperatures, at which time the liquid evaporates. On cooling a homogeneous plastic mass is produced. See **aerogel; plastic dispersion; plastisol; polyvinyl chloride dispersion plastic; volatile.**

organosol diluent In an organosol, a liquid component that has little or no solvating action on the plastic. Its purpose is to modify the action of the dispersant. The term *diluent* is commonly used in place of the term *plasticizer.* See **diluent; solvating action.**

organosol dispersant A liquid component that has a solvation action on the plastic that aids in dispersing and suspending it. It prevents coalescing.

organosol nonaqueous dispersion Bulk or bead-type plastic that has been ground to a relatively fine powder that can be dispersed in a nonaqueous media. The low practical limit for particle size is 10 μm. See **coating, waterborne system; polymerization, aqueous.**

organosol stabilizer One of the dioctyl-tin mercaptides, sulphides and oxides of tin-alkyd or aryl, organotin mercaptides, or maleate compounds. These provide high stabilizing efficiency, compatibility, and impartation of clarity for vinyl.

organotin catalyst See **catalyst; foamed polyurethane.**

orientation A controlled system of stretching thermoplastic molecules in unioriented unidirection (UD) or bioriented biaxial direction (BD) to improve their strength, stiffness, optics, electrical, or other properties and thereby improve product performance-to-cost. This technique is used during the processing of many different products such as films, sheets, pipes, and fibers. Depending on the properties of a specific plastic, the stretch ratio may vary from 2½:1 to as high as 10:1. Some specialty films may have an even higher stretch ratio. Used for almost a century, orientation became prominent during the 1930s for stretching fibers up to 10 times. Later it was adapted principally to films and other products such as stretched blow-molded bottles taking advantage of this feature. Practically all TPs can undergo orientation, although certain types find it particularly advantageous (PET, PP, PVC, PE, PS, PVDC, PVA, PC, etc.). The largest market for plastics worldwide, consuming about 20wt% of the total, is oriented plastic film. Stretching can take place in-line or off-line with or without tenter frames using the appropriate temperature-pull rates. During extrusion of blown films, flat films, sheets, and fibers, their in-line rate of travel can be increased. Off-line tenter frames are predominantly used. Extruded stretched-blown bottles use mechanical devices. See **blow molding, injection-with-rotation; blow molding, stretched; concrete reinforced; directional property; extruder-blown film orientation; extruder flat-film orientation; fiber drawing; forming, cold-drawing; molecular-arrangement structure; orientation, shrink-film; orientation, tenter frame and roll; packaging, contour; packaging, shrink-wrap; plastic memory; stress, normal; thermoforming, blister package; thermoforming, shrink wrapping.**

orientation, accidental An accident that occurs during the processing of thermoplastics that may be acceptable. With the usual proper process control, there is no accidental orientation. Frozen-in stresses, caused by accidental orientation, can be extremely damaging if parts are subjected to environmental stress cracking or crazing in the presence of heat or chemicals. Initially, the molecules are relaxed. Molecules in the amorphous regions are in random coils; those in crystalline regions are relatively straight and folded. During processing (injection, extrusion, etc.) the molecules tend to be more oriented than relaxed, particularly when the melt is subjected to excessive shearing action. After temperature, time, and pressure are applied and the melt goes through restrictions (mold, die, etc.), the molecules tend to be stretched and aligned in a parallel form. The result can be undesirable changes in the directional properties and dimensions immediately when processed or thereafter when in use if stress relaxation occurs. See **adhesive, solvent; amorphous plastic; cracking; crazing; crystalline plastic; engineering plastic; injection-molding melt-shear behavior; melt-shear rate.**

orientation and chemical property Simple orientation alone increases sorption and solubility, but when it induces crystallization, the overall net effect is a decrease in these properties. Similarly, residual stresses in the structural foamed plastics make them more susceptible to chemical attack. Orientation of amorphous plastics affects molecular mobility and permeability in similar ways; permeability decreases in the direction of orientation and increases perpendicular to it. Orientation of crystallizable or crystalline plastics decreases permeability. Many properties significantly increase such as stiffness, strength, and toughness as well as resistance to liquid and gas permeation, crazing, microcracks, and others in the direction or plane of orientation. Orientation provides a means of tailoring and improving the properties of plastics. See **amorphous plastic; crystalline plastic.**

orientation and cost The process of orientation is fairly expensive, and increases the cost per unit weight of the product. However, it also increases the yield considerably and improves quality greatly. Many products (film, sheet, fiber, pipe, etc.) are made much stronger, more flexible, and tougher, which results in significant cost advantages. The maximum ultimate economic value depends on the relative cost of stretching versus the increase in yield and properties.

orientation and crystallization When crystallizable plastics have been melted and quenched into the amorphous state and then are oriented by mechanical stress, such orientation may make the molecules parallel enough to induce crystallization. This is the main reason for the possible confusion between crystallinity and orientation. When crystallites already exist in the amorphous matrix, orientation will make these crystallites parallel. If a plastic crystallizes too far in the melt, it may not contain enough amorphous matrix to permit orientation and will break during stretching. (Most partially crystalline plastics can be drawn four to five times.) The degree of crystallinity is influenced by the rate at which the melt is cooled. This is utilized in the fabrication operations to help control the degree of crystallinity. The balance of properties can be slightly altered in this manner, allowing some control over such parameters as container volume, stiffness, warpage, and brittleness. Nucleating agents are available that can promote more rapid crystallization resulting in faster cycle times. See **amorphous plastic; crystalline plastic; crystallization.**

orientation and electrical property Orientation decreases the dissipation factor in the direction of the orientation, and increases occur perpendicular to orientation. Since modulus changes in the opposite way, this indicates that polar vibrations along a stretched plastic molecule are decreased, while transverse vibrations between the stretched molecules are increased. See **electrical dissipation factor; vibration.**

orientation and fiber reinforced See **directional property; reinforced plastic.**

orientation and glassy state An important transition occurs in the structure of both crystalline and noncrystalline plastics. This is the point at which they transition out of the so-called glassy state. Rigidity and brittleness characterize the glassy state because the molecules are too close together to allow extensive slipping motion between each other. When the glass transition (T_g) is above the range of the normal temperatures to which the part is expected to be subjected, it is possible to blend in materials that can produce the T_g of the desired mix. This action yields more flexible, tougher plastics. See **glassy state; glass transition temperature.**

orientation and heat-shrinkability Oriented heat-shrinkable plastic products are found in flat, tubular film, and tubular sheet. The usual orientation is terminated (frozen) downstream of a stretching operation when a cold enough temperature is achieved. Reversing this operation occurs when the product is subjected to a sufficiently high temperature. This reheating results in the product shrinking and is used in part assemblies, tubular or flat communication cable wraps, furniture webbing, medical devices, and wire and pipe fitting connections or joints. See **electrical connector; joining-and-bonding method; orientation, thermal characteristic; pipe; shrinkage; sterilization radiation; tubing, heat-shrinkable.**

orientation and mechanical property Mechanical properties depend directly on the relationship between the axis of orientation of the plastic molecules and the axis of mechanical stress on the molecules. Modulus and strength increase in the direction of stretch and decrease in the perpendicular direction. This is the mechanism of pseudoplastic and thixotropic rheology that is typical of non-Newtonian plastic-flow behavior. After processing, some loss in properties may occur when subjected to heat during further processing, such as thermoforming, heat sealing, and solvent sealing. See **directional property; orientation and heat-shrinkability; rheology; thixotropy; viscosity, non-Newtonian.**

orientation and mobility Orientation requires considerable mobility of large segments of the plastic molecules. It cannot occur below the glass transition temperature (T_g). The plastic temperature is taken just above T_g. See **glass transition temperature.**

orientation and optical property Biaxial orientation of crystalline plastics generally improves clarity of films. This occurs because stretching breaks up large crystalline structures into smaller than the wavelength of visible light. With uniaxial orientation, the result is an anisotropic refractive index and thus birefringence, especially in crystalline plastics. See **birefringence; crystalline plastic; directional property, anisotropic; light index of refraction.**

orientation and processability See **orientation; orientation and crystallization; orientation, tenter frame and roll.**

orientation, balance Uniform stretch in the machine and transverse directions. See **directional property, machine; directional property, transverse.**

orientation, biaxial (BO) The stretching of material in two directions (biaxially) at right angles—along machine direction and across or transverse direction. The amount of stretch in both directions varies, depending on product requirements. If both are equal, then it is a balanced orientation. Small to large lines are used. For example, one of the largest cast-oriented PET film lines in the world (DuPont's plant in Dumphries, Scotland, built by Kampf GmbH & Co., Germany) produces film that is 9 m wide after MD and TD stretching. The film is wound in one piece at up to 480 m/min. A take-up roll weight is 13 T using a high-stiffness reinforced-plastic carbon fiber or epoxy core. A very large oriented polypropylene-plastic coextruded-film line (Applied Extrusion Technologies, Inc., New Castle, DE) uses a massive tenter oven and turret winder built by Bruckner (Maschinenbau, Germany) and produces 10 m wide film at up to 400 m/min or 50 million lb/yr. See **directional property, biaxial; forming, scrapless.**

orientation, blow-molding See **blow molding, injection-with-rotation; blow molding, stretched.**

orientation, blown-film See **extruder blown-film orientation.**

orientation, characteristic Some general rules for orienting by stretching are that (1) the lowest temperature will give the greatest orientation (tensile strength, etc.), (2) the highest rate of stretching will give the greatest orientation at a given temperature and percent stretch, (3) the highest percent stretch will give the greatest orientation at a given temperature and rate of stretching, and (4) the greatest quench rate will preserve the most orientation under any stretching condition. With orientation, the thickness is reduced, and the surface enlarged. If film is longitudinally stretched, its thickness and width are reduced in the same ratio. If lateral or transverse contraction is prevented, stretching reduces the thickness only.

orientation, cold-stretching Orienting plastics by cold stretching—that is, below its glass transition temperature (T_g). There has to be sufficient internal friction to convert mechanical into thermal energy, thus producing local heating above T_g. This occurs characteristically in the necking of fibers during cold drawing. See **glass transition temperature.**

orientation, electrical See **dielectric property.**

orientation, film See **extruder flat-film orientation.**

orientation, injection with rotation See **blow molding, injection-with-rotation.**

orientation, molecular The alignment of the polymer crystalline structure to produce a highly aligned structure. See **crystalline plastic; light scattering.**

orientation, random A condition of a crystalline aggregate in which the constituent crystals have orientation completely random with respect to one another. See **crystalline plastic.**

orientation, shrink-film Stretching or orienting film during manufacture. See **orientation; packaging, contour; packaging, shrink-wrap tunnel.**

orientation stretch forming See **thermoforming, stretch.**

orientation temperature It is normally 60 to 75% of the range between the plastic's glass transition temperature and melting point. See **glass transition temperature; temperature, softening range.**

orientation, tenter frame and roll Equipment can be used in-line or off-line to gain output yield and properties. For example, ordinary blown- or cast-film lines use a machine-direction orienter on the front end of biaxially oriented film-extrusion lines. Another common use is casting lines for nonbiaxial strapping. If only the machine direction is to be stretched, a series of precision-controlled heated rolls are used. Film is fed through a series of rolls where it is sequentially heated, drawn around rolls that increase in rotational speed providing the stretching action, annealed around larger diameter roll(s), and cooled on a final roll. Generally, the orientation temperature is 60 to 75% between the plastic's glass transition temperature and melting point. Amount of orientation is dependent on the speed of the rolls. For biorientation or balanced orientation to be produced, basically a tenter frame follows the series of rolls. The frame is located inside a closely controlled temperature airflow oven. Some type of mechanical gripping clamps will hold the edges, both sides, of the film or sheet. These steel clamps that may be about 4 in. (10 cm) long, one after another as close as possible, fit on a steel conveyor belt that follows a flat path. The flat path for both conveyors goes through the oven at a required angle that relates to the amount of stretch that will occur in the transverse direction. Prior to leaving the oven, temperature is reduced retaining the orientation developed. See **calender; directional property, machine; directional property, transverse; extruder flat film; extruder sheet.**

orientation tenter mark A visible deformation on the side edge of a material that is due to the pressure from the clips and clamps; this trim is cut. See **cutter.**

orientation, thermal characteristic These oriented plastics are considered permanent, heat-stable materials. However, the stretching decreases dimensional stability at higher temperatures. This situation is not a problem since these types of materials are not exposed to the higher temperatures in service. For the heat-shrink applications, the high heat provides the shrinkage capability. See **orientation and heat-shrinkability; thermal analysis.**

orientation, transverse See **directional property, transverse.**

orientation, uniaxial (UO) Stretching in only one direction, which is usually in the machine direction. Also called *axial orientation* or *monoaxial orientation.* See **directional property, machine; directional property, transverse.**

orientation, wet-stretching For plastics whose glass transition temperature (T_g) is above their decomposition temperature, orientation can be accomplished by swelling them temporarily with plasticizing liquids to lower their T_g of the total mass, particularly in solution processing. For example, cellulose viscous films and fibers can be drawn during coagulation. Final removal of the solvent makes the orientation permanent.

orientation with rotation See **blow molding, injection-with-rotation.**

orifice An opening, such as that in an extrusion die or pultrusion die. See **die; reinforced-plastic pultrusion.**

orifice bushing See **die orifice bushing.**

O-ring See **sealing, O-ring.**

ornamental encapsulation See **casting; casting, liquid; encapsulation.**

orthotropic property See **directional property, orthotropic.**

oscillating rheometer See **rheometer, dynamic.**

osmosis The diffusion of a substance through a semipermeable membrane (includes plastics) that typically separates a solvent and a solution that tend to equalize their concentrations. An example is the passage of a solvent from a mass of pure solvent into solution or from a less to a more concentrated solution through a membrane that is permeable to the solvent but not the solute. See **dialysis.**

osmosis, electro- See **electrophoresis.**

osmosis, reverse An osmosis system that is used as a method to desalt sea water, recover waste in pollution control, or treat industrial water. See **waste; water, desalination of.**

outgassing The release of a volatile substance from a plastic during heat processing (injection, casting, etc.) or from a plastic part during vacuum metallizing. Each processing method has techniques for removal of the solvents such as venting and bumping. See **mold breathing; plastic material outgassing; venting; volatile.**

out-of-round Nonuniform radius or diameter.

output See **fabricating output.**

output transient response The output of a system that is related to the natural response of a system and eventually disappears if the external force continues unchanged.

outsourcing See **fabricating outsourcing.**

oven, tunnel See **packaging, shrink-wrap tunnel.**

overmolding See **injection molding, two-shot.**

overrun See **production overrun analysis.**

oxidation **1.** The addition of oxygen to a compound. **2.** A chemical reaction that involves a combination with oxygen to form new compounds or prepare a plastic surface. See **transcrystalline growth; Wacker process; waste, pressure cooking. 3.** The degradation of a material through contact with air. See **antioxidant agent; oxygen; ozone; reactor, vapor-phase. 4.** See **calcining.**

oxidation degradation, thermal Additive agents are commonly used to protect plastics against thermal oxidation degradation, although some plastics literally cannot degrade. With certain plastics a chemical structural modification is made to resist degradation. See **antioxidant agent; antiozonant agent; light stabilizer; oxidizing agent; recycling steel with vinyl scrap; ultraviolet absorber; ultraviolet stabilizer.**

oxide The product of the combination of oxygen with an element, such as zinc oxide.
oxidizing agent A substance that is used to inhibit aging that is caused by natural oxidation. See **chlorine.**
oxygen (O_2) A colorless, tasteless, odorless gas that constitutes approximately one-fifth of the atmosphere. It is found in almost all the carbon compounds used in the production of plastics.
oxygen barrier See **barrier; coating, oxygen-barrier removable.**
oxygen gas transmission rate See **test, oxygen gas transmission rate.**
oxygen index See **limiting index oxygen.**
oxygen, liquid See **polyarylene ether phosphine oxide plastic.**
oxygen scavenger See **packaging, oxygen-scavenger food; scavenger.**
ozone (O_3) An almost colorless gaseous form of oxygen (O_2) that has an odor similar to weak chlorine. Ozone is generated by electrical discharge, but a more important source is the photolysis of oxygen on sunny days. It is also the chemical by-product of a chemical reaction that takes place between volatile organic compounds and nitrogen oxides when heated by the sun. It is among the primary emissions of combustion (exhaust from auto, truck, factories, etc.) and the processing of petroleum products. In the atmosphere, there is ground-level ozone or smog. See **antioxidant agent; antiozonant agent; electrical corona; Petlite; polychlorofluorocarbon; protocol, Kyoto; protocol, Montreal.**
ozone depletion potential See **protocol, Montreal.**
ozonolysis **1.** The oxidation of an organic material by means of ozone. **2.** The use of ozone in analytical chemistry studies.

P

packaging The packaging industry and its technology is the major outlet for plastics where it consumes about 25wt% of all plastics with building and construction in second place consuming about 20wt%. If plastic packaging were not used, the amount of packaging contents (food, etc.) discarded from USA households would more than double. Plastics are the most efficient packaging materials due to their higher product-to-package ratio as compared to other materials. One ounce of plastic packaging can hold about 34 ounces of product. A comparison of product delivered per ounce of packaging material shows 34.0 plastics, 21.7 aluminum, 6.9 paper, 5.6 steel, and 1.8 glass. See **bottle; container; landfill and degradation; Petlite; plastic growth; plastic markets, product and material; plastic myth and fact; waste and plastic packaging.**

packaging, aseptic In food processing, a process condition that renders a processed food product essentially free of microorganisms capable of growing in the food in unrefrigerated distribution and storage conditions. In aseptic food packaging, presterilized containers are filled with aseptic foods and then hermetically sealed in a commercially sterile atmosphere. See **packaging, retortable-pouch; sterilization.**

packaging bag See **packaging, grocery-bag; slip additive; test, bag drop; waste and plastic bag.**

packaging, bag-in-box (BIB) A sealed, sprouted (small to large, with or without dispensing valves) plastic bag inside a rigid container, generally for packaging liquid products. The outer box may be made of disposable corrugated cardboard or disposable or reusable plastic or wood. BIBs offer space and cost efficiencies. The empty BIBs in a warehouse may occupy as little as 20% of the space required for the equivalent volume in glass or rigid plastic and may reduce shipping weight. See **material handling.**

packaging, beverage-can Aluminum cans dominate the U.S. market for soft drink containers with about 70% of the market, but PET and glass compete for second place. See **blow molding; bottle; market.**

packaging biological substances Many biological substances are classified as hazardous and require specialty packaging in which plastics play an important role to meet strict requirements. See **biological activity; hazard.**

packaging, blister A package in which a thin plastic film or sheet is formed so that a product is placed in the blister, backed up by a material (plastic, paper, aluminum, etc.), and sealed. Also called *blister-carded packaging*. See **thermoforming, blister package.**

packaging, breathable-film A breathable film that is identified as controlled-atmospheric packaging (CAP) and substantially extends the shelf life of perishables by regulating oxygen, carbon dioxide, and moisture permeability. This type packaging has extended global trade. One type is used in horticulture and medicine packaging and was introduced in 1994 by researchers in Brunel University, Oxbridge, UK. It has a two-plastic layer structure that contains small holes that open and close as the temperature changes. The principle is the same as that used in bimetallic strips (thermocouples, etc.) and takes advantage of differences in coefficients of linear thermal expansion; as the temperature rises, the edges of the holes peel away. Typically, PE laminated to thermoplastic polyester with an acrylic adhesive is ideal for packaging vegetables and fruits. Its structure can be modified to meet a wide range of respiratory rates. Other applications include medical dressings for burns, drug-controlled release-delivery systems, variable vapor barriers for shoes and clothing, and temperature-sensitive warning labels. See **barrier plastic; coefficient of linear thermal expansion; packaging, modified-atmosphere; porous, micro-.**

packaging, bubble-pack A plastic cushioning material that is used in packaging, usually laminated thermoplastic films that incorporate air bubble pockets. See **packaging, loose-fill plastic.**

packaging cap, tamper-proof See **mold, collapsible-core.**

packaging, clamshell See **thermoforming, clamshell.**

packaging clasp A device that is commonly used to secure tops and lids on different type packages. Their holding power can be obtained from simple friction between the joint surfaces or from positive mechanical engagement. Plastic flexing capability is important because the parts must flex to release the clasp and spring back to their original position.

packaging container See **bottle; coating, oxygen-barrier removable; container.**

packaging container content misrepresentation Unwitting errors with upper- and lowercase letters can dramatically misrepresent package contents. For example, there is a drastic difference between 100 ML and 100 ml or 100 million liters and 100 milliliters. Some designers prefer using capital letters for contents designations on the label. Thus, with metric usage fluid ounces are replaced by milliliters, quarts are replaced by liters, pounds or dry ounces are replaced by grams or kilograms, and so on. Metric unit short forms are symbols, not abbreviations and are never followed by a period unless the symbol is the last word in a sentence. Metric symbols are always used in singular form, without adding an *s* to indicate quantity. See **measurement.**

packaging, contour A thin plastic film or sheet that is formed over a product and usually simultaneously sealed to a paperboard or plastic backing. The product serves as a mold. Also called *skin packaging.* See **orientation; thermoforming, blister-package; thermoforming, shrink-wrapping.**

packaging, dual-ovenable tray (DOT) In the past thermoset plastic materials were used for DOTs, but nearly all now are thermoplastics such as CPET. DOTs for frozen foods have been a major outlet for plastics.

packaging, edge-bowing The inward bowing that is characteristic of the edges of open boxes.

packaging, electronic The size reduction of electronic components and the higher-density packing of components on computer chips make the devices susceptible to static damage. In many cases, the environment can be adjusted through increased humidity, antistatic mats, or ionizing sprays to control the problem. During transportation and storage, static protection is critical. Components must be protected from stray electric fields such as electric motors and discharges that can destroy microcircuits. One method of protection is to pack them in antistatic plastic-film bags. See **antistatic agent; design, biomedical-product; electromagnetic interference; electronic microminiaturization; integrated circuit, plastic; printed circuit board; static charge.**

packaging film See **extruder flat or blown film.**

packaging, flexible See **packaging, retortable-pouch.**

packaging, food Most packaged foods require a barrier against gases, flavors, or odors to maintain product quality and provide acceptable shelf life. Baked foods usually need moisture protection, while fresh meats and vegetables require low or controlled exposure to oxygen to maximize shelf life and consumer appeal. Polyethylene films, both single and multilayer, are widely used to package such products. Certain key properties and processing conditions affect the permeability of PE. For example, with blown film, factors such as the blow-up ratio, frost-line height, and die-gap width can be used to control permeability. At least 10wt% of the U.S. food supply is packaged in plastics. See **adulterant; barrier plastic; closure; extruder-blown film; extruder flat film; mayonnaise jar; packaging, aseptic; packaging, dual-ovenable tray; packaging, breathable-film; Petlite; plastic and food; scavenger; test, organoleptic; test, oxygen gas transmission rate; test, water-vapor transmission rate; waste; waste, solid food.**

packaging form, fill, and seal See **thermoforming, form, fill, and seal.**

packaging, grocery-bag Polyethylene sack or T-shirt bags are stronger than paper bags, take up 30% less storage space, provide water and puncture resistance, and are recyclable. See **additive, slip; environment and public opinion; extruder blown film-bag manufacturing; test, bag-drop impact; waste, plastic-bag.**

packaging, hot-fill Thin-wall plastics are used to hot fill (blow-molded bottles, thermoformed containers, etc.) without sagging during filling and to maintain mechanical properties such as impact strength and stiffness in temperatures from at least −40°C to 120°C. The plastics that are used include special grades of PEN, PET, PP, PS, and PVC. See **plastic material selection.**

packaging identification See **barcode; label; laser marking; printing, screen.**

packaging, loose-fill plastic Principally polyethylene and polystyrene foam in different shapes, such as peanuts and pretzels. See **packaging, bubble-pack; recycling.**

packaging market The largest U.S. market for plastics is in packaging products, where about 30wt% is consumed with sales at about $40 billion. Saleswise about 30% is HDPE, 16% LLDPE, 14% TP polyester, 13% PP, 11% LDPE, and 16% others. See **market; packaging; plastic markets, product and material.**

packaging, modified-atmosphere (MAT) A packaging method that uses special mixtures of gases (carbon dioxide, nitrogen, oxygen, or their combinations) and polyolefin blown- or cast-barrier films to change the ambient atmosphere influencing its food content. Film construction included polyolefin plastomers (POP), EVOH/PVDC, ULDPE, LLDPE, PP, SB, LDPE/PA/EVOH, and PVDC/coated PET/LDPE. The hermetically sealed MAT extends the shelf life of red meat, skinless turkey breast, chicken, half-baked bread, pizza crust, and bagels and allows them to be presented in a palatable manner. For example, the microbial growth of red meat is retarded and maintains a deoxygenated blue or gray color until the meat is placed on display. Ground beef normally may last three to four days but with MAT can go to 14 days before the sell-by date. This gas-flushed MAT permits grocers to sell uncooked fresh meats, marinated varieties, and ready-made meals for quick preparation for round-the-clock sales. This more expensive (but with reduced costs in service) and sophisticated packaging concept of using a gas-flushed barrier film is not new compared to the traditional multilayer method. See **barrier plastic; packaging, film-breathable; polyolefin plastomer plastic; seal; Appendix A, List of Abbreviations.**

packaging, oxygen-scavenger food An impregnated plastic that has chemically reactive additives that absorb oxygen, ethyl, and other agents of spoilage inside the package once it has been sealed. Food-package types include flexible pouches, PET bottles, microwave trays, and cartons (coated plastic and paper). When such films are combined with conventional rigid- or flexible-barrier systems, they can allow food packagers to greatly retard spoilage and prolong shelf life. See **scavenger.**

packaging, peelable-film Peelable film in case-ready ground-beef packages adds color and shelf life. The Cryovac Division of W. R. Grace & Co. uses a peelable barrier lid and foam tray system. An oxygen barrier structure is peeled off, leaving an oxygen-permeable film over the meat.

packaging, pouch heat-sealed wraps and reusable containers These packaging systems help keep food fresh and free of contamination and conserve the resources that went into producing the food. It has been estimated that each pound of plastic packaging can reduce up to 1.7 pounds of food waste. See **contamination.**

packaging, retortable-pouch Superior flavor retention and longer shelf life are principal advantages of single or laminated plastic (such as PP, PC, PEI, CPET, and EVOH), with or without aluminum foil or paper. They are made impervious to light, air, most other gases, microbial organisms, water, and most other liquids. Many applications require them to be capable of withstanding temperatures of at least 250°F (121°C) for at least 20 minutes. Different processing methods are used, such as blow molding and thermoforming. The U.S. converted flexible-packaging industry consumes about 7 billion lb, of which 75% is plastics, 22% is paper, and 3% is aluminum foil. Also called *retortable container* or *flexible packaging*. See **barrier; blow molding; packaging, aseptic; thermoforming, form, fill, and seal.**

packaging seal See **seal; sterilization.**

packaging, shrink-wrap See **orientation, shrink-film; packaging, contour; thermoforming, blister-package.**

packaging, shrink-wrap tunnel An oven in the form of a tunnel that is mounted over or contains a continuous conveyor belt and that is used to shrink oriented films in the shrink packaging process. A hot-air blower is used to provide the heat required. See **orientation, shrink-film.**

packaging static charge See **antistatic agent.**

packaging type Various types of plastic packages provide high visibility for the products they contain and protect. Examples include carded blister packs, windowed, clamshell, and skin packages. See **bottle; container; packaging; thermoforming.**

packaging unitization The assembled group of containers or parts in a single load that can be handled as a unit throughout a distribution system. See **material handling.**

packaging zipper See **thermoforming, form, fill, and seal.**

packing **1.** The operation of placing solid materials or products in shipping containers in such a way as to secure maximum space economy and freedom from damage. See **foam. 2.** An inert material that is used in chemical-distillation columns. **3**. Molecular packing during the synthesis of polymers. See **chemical synthesis. 4.** A collar or gasket that is used to seal mechanical devices and is often made of plastic elastomers. See **elastomer. 5.** See **cushion; injection-molding melt cushion; mold-filling monitoring.**

packing factor The ratio of occupied volume to bulk volume; occupied volume per unit of total volume. See **bulk factor; cushion.**

PACT See **design, medical-device.**

pad See **cushion.**

paddle agitator See **mixer, paddle-agitator.**

paint A material that is designed to adhere to a substrate and act as a thin, plasticlike layer. A liquid mixture is applied to a surface to form, on drying, a protective or decorative film. Paints consist of pigments dispersed in liquid vehicles, most of which include different types of plastics to meet different performance or cost requirements. There are aqueous and solventborne paints. Also called *coating* or *finish*. See **aluminum stearate; antimony trioxide; bitumen; calcium sulfide; carbon disulfide; chinese white; coating; crocking; decorating; linseed oil; powder coating; primer; varnish.**

paint baking See **finish, baking.**

paint coating, in-mold The injected-paint technology from Battenfeld paints injection-molding parts in the mold. The process takes place in a coinjection molding machine with modifications to the nozzle and the screw. See **coinjection molding; injection molding, in-mold.**

paint dryer See **aluminum stearate.**

paint emulsion A latex paint that is composed of two dispersions—dry powders (colorants, fillers, extenders) and plastic dispersions. They are characterized by a water-dispersed binder. The principal types are styrene-butadiene, polyvinyl acetate, and acrylic plastics. The percentage composition generally is 25 to 30vol% dry ingredients, 40% latex, and 20 to 30% water, plus a small amount of stabilizer. Their unique properties are ease of application, absence of disagreeable odor, and nonflammability, and they are used indoors and outdoors. See **emulsion.**

paint, fill and wipe See **decorating, fill and wipe.**

paint framing defect A paint defect that consists of excessive film buildup that is caused by the surface tension near a sharp radius. Visually it is perceived as a hump that runs parallel to the radius. See **defect.**

painting See **coating; colorant; decorating.**

painting plastic Certain plastic products that require painting may need special considerations in terms of wettability and paint adhesion because they may lack the required high surface tension. Different pretreatments are used, such as solvent etching, flame treatment, plasma treatment, and sulphonation. Some plastics may be sensitive to certain solvents, so care has to be taken not to damage the plastic. See **solvent; stress-cracking failure; surface pretreatment.**

paint line A line where two paints meet.

paint, luminous See **calcium sulfide.**

paint, maintenance See **coating, air-drying alkyd plastic.**

paint, oil-reactive plastic A synthetic plastic that is used in the manufacture of a paint and varnish that reacts chemically with a drying oil during the process of solution. At moderate temperature it will dissolve in, disperse in, or react with drying oils to give a homogeneous film of modified characteristics.

paint remover See **carbon disulfide.**

paint, solventless See **powder coating.**

paint, spray See **air atomization; spray-paint coating.**

paint spray and wipe See **decorating, fill-and-wipe.**

paint surface See **defect; surface finish.**
paint, water-base See **latex.**
pallet A portable platform that is used to store products. The industrialized countries have more pallets than people. The United States has about 1.6 billion, and Europe has at least 0.5 billion. Virtually all are wood. Plastic pallets weigh about 20 kg (44 lb), and typical sizes are 1.0 × 1.2 m or 1.1 × 1.3 m. High-density polyethylene plastics are predominantly used. Plastic pallets have a 4:1 price disadvantage (wood cost is about $17) but more are being put into use because of the savings generated by longer reuse, use of recycled plastics, greater use of robots requiring uniform size/weight, closed-loop in-plant shipping, long life, reduced load damage, easy cleaning, reduced worker injury, chemical inertness, moisture-proof nature, no harbor for pests, lack of splinters and exposed nails, nestability, plant sanitation, and, with fire-retardant agent, fire resistance. An important criterion for pallets, where plastics have had limitations based on past performances, concerns taking at least a load of one ton in racking. See **recycling.**
paper A thin, fibrous, nonwoven sheet material that is produced from cotton, wood pulp, plastic fibers, or asbestos and that uses established paper-making processes such as the fourdrinier wet process and carding dry process. It is used, for example, as a decorative surfacing sheet for laminated plastics. See **cellulose, alpha; fabric, nonwoven; fabric, nonwoven mechanical; fiber carding; fourdrinier; kraft paper; plastic paper; wood pulp, paper.**
paper, bogus A paper or paperboard that is manufactured principally from old or inferior papers or low-grade stock in imitation of grades using a higher quality of raw materials.
paper, deinked A paper that uses fibers that are made from preconsumer and postconsumer waste. This material would otherwise be dumped in a landfill. See **landfill and degradation.**
paper, rag An exceptionally tough paper that can be used in the fabrication of industrial laminated plastics. See **laminate.**
paper recycled See **recycled paper; waste.**
paraffin wax A white, translucent solid that consists of a mixture of solid hydrocarbons, chiefly of the methane series, and is obtained from crude oil. It is used as a parting agent for plastics. See **wax.**
parallax See **light aberration.**
parallel property See **directional property, parallel.**
parameter An arbitrary constant, as distinguished from a fixed or absolute constant. Any desired numerical value may be given a parameter.
parametric Dynamically linked to a list of specific parameters, where changes to them result in changes to a geometric drawing. See **modeling parametric.**
parison See **blow molding, extruder, parison.**
Parkesine plastic A plastic that was introduced commercially in 1862 by the Englishman Alexander Parkes. Chloroform and caster oil were mixed to produce a substance as hard as horn but as flexible as leather and capable of being cast, carved, or stamped and painted. It could be produced at a lower cost than the popular gutta percha. Unfortunately the material never went into production because the factory that was formed in 1866 was liquidated in 1868. No further action was taken with this material.
park, recycled See **landfill, recycled.**
part handling Although the finished part can be removed in many different ways from the primary production equipment, special consideration should be given to flexibility in output rate, method of handling secondary operations, packaging or storage, product identification, and quality-control procedures. See **conveyor; material handling; quality control; robot.**
part-handling equipment (PHE) The logic and approach used in materials handling also applies to the use of PHE to move processed products. Since decorating, machining, assembly, packaging, and many other postfabricating operations tend to be simple, repetitive tasks, they often lend themselves to PHE automation. See **auxiliary equipment; extractor; mold eyebolt and hole.**
particle Any discrete unit of material structure. See **antiparticle.**
particleboard A generic term for a panel that is fabricated from lignocellulose materials (wood) primarily in the form of discrete pieces or particles, as distinguished from fibers, that are combined with a plastic such as phenolic or urea plastic. It is bonded together under heat and pressure either in a press or extruder. See **extruder; phenolic plastic; press; urea.**
particulate filler An additive, such as calcium carbonate, talc, short fibers (wood, glass, etc.), or carbon black, that reduces formulation costs. See **filler; mill, tube.**
parting agent See **mold-release agent.**
parting line See **mold-parting line.**
parting-line control See **injection molding process-control parting line.**
part per hundred (phr) A relative unit of concentration of parts of one substance per 100 parts of another. Weight, volume, count, or other suitable unit of measure can measure the parts. It is used often to denote the composition of a blend or mixture in terms of parts of a minor ingredient, such as plasticizer or per 100 parts of the plastics. See **material-blending letdown ratio.**
part per hundred million (pphm) A relative unit of concentration, similar to parts per hundred. It is used often to denote a very small concentration of a substance, such as impurity in a plastic or in air.
part per million (ppm) A relative unit of small concentrations of material or substance as the number of its parts (arbitrary quantity) per million parts of medium consisting of another material or substance.
part treatment See **surface treatment.**
parylene plastic A thermoplastic that is made by vapor-phase polymerization of p-xylene. Hot p-xylene vapors are cooled to condense the monomer and deposit it as a plastic in the form of a thin, uniform coating on a substrate, such as fabric or an electronic device. Its melting point

ranges from 290 to 400°C (554 to 752°F), and the glass transition temperature ranges from 60 to 100°C (140 to 212°F). Their physical properties are unaffected by thermal cycles from 2°K (−271°C) to room temperature. They are generally insoluble up to 150°C (302°F). Their first significant commercial application was as dielectric film in high-performance precision electrical capacitors, followed by use in circuit boards and electronic module coatings. Free-standing film can be produced ultrathin to 350A (3 micron); they are called *pellicles* and are used as beam splitters in optical instruments, windows for nuclear radiation measuring devices, dielectric supports for planar capacitors, and extremely fast-responding, low-mass thermistors and thermocouples. See **dielectric; glass transition temperature; melting temperature; temperature.**

Pascal **1.** A SI unit of measurement of pressure equal to the pressure resulting from a force of 1 Newton acting uniformly over an area of 1 square meter. It is used to denote the pressure of mechanical behavior of materials under pressure. **2.** See **computer Pascal.**

paste A material compound and adhesive composition of semisolid consistency, usually dispersed in water. See **mixer, double-arm; mixer, paddle agitator; extruder paste.**

paste metering blade See **doctor blade.**

pastel See **color, pastel.**

patent See **legal matter: patent.**

patent pooling with competitor See **legal matter: patent pooling with competitor.**

pattern surface waviness See **plastic, low-profile.**

pearlescent See **color, special-effect; pigment, pearlescent.**

pectin See **gel, pectin.**

peel ply See **reinforced-plastic peel ply.**

peel strength See **adhesive peel strength.**

peel torque See **sandwich peel torque.**

peening **1.** Hammering on plastics for shaping, bending, cutting, or decorating material. See **swaging.** **2.** The service life of certain plastics can be extended by shot peening. In shot peening, parts are bombarded with an intense stream of tiny metal, ceramic, or plastic balls, producing a highly shocked and compressed material on their surface. Overlapping layers of the material provide a thin, uniform layer that becomes resistant to cracks and fatigue. Work in this technique has also included the use of a high-powered laser beam. See **surface finish.**

pegging See **production pegging.**

pellet In the production of thermoplastic finished products, a primary form of dry material to be processed. Pellets offer the following advantages, particularly when they are uniform in shape and size: (1) more accurate distribution of plastics into a process, (2) simpler feeding system with fewer feeders, (3) dust-free handling, (4) easier cleaning between changes in feedstock, (5) fewer unsatisfactory finished products, (6) greater extrusion (injection molding, etc.) capacity, and (7) lower shipping costs as a result of higher feed-bulk density. The disadvantages of pellets are the plastic's additional heating cycle (extending residence time) and the additional cost. See **concentrate; dicer; die-face pelletizer; drying; fine; material blocking; material, cutting burr-free; plastic feed form; plastic material; preform.**

pellet color sorter A system that detects and separates off-color or contaminated pelletized or granular materials from acceptable materials. Separation can be light from dark, dark from light, transparent from opaque, or by color differences. The system detects and automatically rejects particles as small as of at least 0.5 mm. The operating principle is based on the photoelectric eye-sensor light reflectance of the material's different brightness or color. Defective material is ejected within milliseconds. Sorters can accommodate throughputs of at least up to 1,000 lb/h (450 kg/h). See **colorant; postconsumer plastic.**

pelletizing Producing pellets. Compounding extrusion lines usually produce pellets using dry-face dicers or the more popular strand pelletizer that uses underwater, water-ring, and water centrifugal pelletizers. The strand pelletizers use two basic methods. One method produces strands usually 0.125 in. (3.2 mm) in diameter and is called the *strand pelletizer.* The hot extruded strands are cooled in a water trough and cut in lengths of about 0.125 in. During this process some degree of fines and longs are produced. They can cause conveying and feeding problems for the processor. Fines caused by the cutter may result in dusting problems. Longs are pieces of strands up to 4 in. (100 mm) long that go through the cutter.

The other method is called *underwater pelletizing.* The die openings are actually underwater or in a moisture atmosphere. A fast-rotating knife almost touching the die face cuts the strands of melt into almost spherical shapes as the strands exit the die openings. The underwater pelletizers were developed to eliminate handling a large number of strands as well as to eliminate fines and longs. When you study these systems, recognize that major challenges exist. There is a die with the very hot melt on one side and cool water on the other side of the die with a pressure drop in the die going back to the breaker plate and screen pack of the extruder. With improper operation the die is frozen solid by the water, resulting in the line's downtime and a time-consuming clean-up mess. Operating procedures have to be prepared and strictly followed. Pelletizers have low to high output rates such as 20 to 15,000 lb (9 to 6,800 kg). See **compounding, shear roll; dicer; die-face pelletizer; fine; melt vibration; mill, roll; plastic material.**

pellet, micro- The usual pellet size is 0.125 by 0.125 in. (0.3 by 0.3 cm). Micropellet diameters range from 0.020 to 0.060 in. (0.051 by 0.153 cm) and are used for applications from rotational molding to color and additive concentrates. They are used in processes such as injection molding and extrusion, where productivity gains occur when compared to the conventional-size larger pellets. The smaller pellets have proportionately more surface area exposed to frictional heating in the plasticator, which leads to faster melting and in turn more uniform mixing and melt flow. See **concentrate.**

Peltier coefficient See **coefficient, Peltier.**

penetrant An agent that is used to increase the speed and ease with which a bath or liquid permeates a material being processed by effectively reducing the interfacial tension between the solid and liquid. See **barrier plastic; permeability.**

pentadiene plastic A plastic that contains pentadiene and is used for adhesives and for liquid rubbers.

pentane gas A gas that is used as a blowing agent in various products, such as expandable plastics, and in foam, such as rigid polyurethane foam insulation and reaction injection molding. This chlorine-free liquid that forms gas requires careful handling since it is flammable; in a plastic it is safe to use. See **expandable polystyrene; foam and blowing agent; polychlorofluorocarbon.**

people and machines As John North Willys, president of Willys-Overland Co. (*Compressed Air Magazine*, January 1919) stated: "I am as adverse to scientific management as I am to scientific employment. The whole theory of scientific management is essentially foreign to the human element and is destructive of individualism and therefore of progress. Pride of work, not pressure, keeps production at top speed. I hold it inhuman to work men as though they were machines; in addition to being inhuman it is bad business."

people's challenge A competition that requires people to meet a target with specific requirements such as size, shape, strength, chemical resistance, aesthetics, and cost. See **computer-aided; cost reduction; definition, art of; design analysis; design technology; processor and competition; risk, acceptable.**

peptide A low-molecular-weight plastic of amino acids. It is arbitrarily designated as having a molecular weight under 10,000. Higher MW species are called polypeptides. See **zein plastic.**

peptizer A compounding material that is used in small proportions to accelerate by chemical action the softening of an elastomer (rubber, plastic elastomer) under the influence of mechanical action, heat, or both. The molecular weight of the plastic is reduced. Peptization of an elastomer allows the compounder to achieve a workable compound viscosity at a high filler loading without reduction in vulcanizate hardness and strength. See **compounding; latex, natural rubber; xylyl mercaptan.**

percentage point A difference of 1% of a base quantity.

percolation The action of a solvent passing through a permeable substance for extracting a soluble constituent. See **leach.**

perfluoroalkoxy plastic A thermoplastic that has a higher temperature limit (260°C or 500°F) than fluorinated ethylene-propylene plastic and is similar to polytetrafluoroethylene in chemical resistance. It is easily processed. It is used in films, coatings, pipes, containers, and linings for chemical apparatus.

perfluorocarbon plastic A plastic whose thermal properties below their melting point of 320°C (608°F) are very similar or somewhat superior to polytetrafluoroethylene (PTFE). It has no room-temperature transition, as does PTFE; thus dimensional changes are much less sensitive to small changes in temperature. It is essentially produces water-clear film in contrast to PTFE.

perfluoromethylvinyl ether elastomer An elastomer that contains about 72wt% of fluorine, resulting in elastomers that are very resistant to alcohol and when cross-linked with peroxide, very resistant to high-performance oils.

performance prediction Avoiding product failures depends, in part, on prediction of the performance of plastic materials and their shapes. A product laboratory or field-testing provides useful and reliable performance data. Engineers and designers continue to develop sophisticated computer methods for calculating stresses in complex structures while using different materials. Computational methods have replaced the oversimplified models of material behavior that were formerly relied on. However, for the new and complex product structures that are being designed to significantly reduce the volume of materials used and, in turn, the product cost, computer analysis is conducted on prototypes already fabricated and undergoing testing. This computer approach can result in early and comprehensive analysis of the effects of conditions such as temperature, loading rate, environment, and material defects on nonstructural or structural reliability. This information is supported by stress-strain behavior that is collected in actual material evaluations.

The finite-element analysis method has greatly enhanced the structural analyst's ability to calculate displacement and strain-stress values in complicated structures that are subjected to arbitrary loading conditions. In its fundamental form, the FEA technique is limited to static, linear elastic analysis. However, advanced FEA computer programs can treat highly nonlinear dynamic problems efficiently. Important features of these programs include their ability to handle sliding interfaces between contacting bodies and the ability to model elastic-plastic material properties. These program features have made possible the analysis of impact problems that in the past had to be handled with very approximate techniques. FEAs have made these analyses much more precise, providing better direction in locating high-stress areas. Final verification of load-carrying capability may require actual testing of the fabricated product based on computational analysis. See **design; finite-element analysis; production performance.**

perfume odor. See **deodorant additive; dichloroethylene; test, organoleptic.**

period The length of time between consecutively recurring conditions; the reciprocal of frequency. See **frequency; measurement.**

periodic Having repeated beginnings and endings.

periodic table A table of the elements that is written in sequence in the order of atomic number or atomic weight. It is arranged in horizontal rows (periods) and vertical columns (groups) to illustrate the occurrence of similarities in properties of elements as a periodic function of the sequence. Its significance is that the names and chemical symbols for the elements are the building blocks for all engineering materials. In the table the elements exhibit a steady trend in properties and are listed in groups. Within each group the elements are quite similar. A given element can be predicted on the basis of its position in the table to resemble the other elements of its group and be intermediate in properties between its adjacent materials. The chief function of the periodic table is to serve as a fundamental framework for the systematic organization of chemistry. Given an understanding of this table with little information, one can predict the properties of many substances, including elements in compounds. See **alkali metal and derivative; atomic number; electron; element; isotope.**

perlite See **building material, perlite.**

perm See **water-vapor transmission.**

permanence Resistance to appreciable change in characteristics with time and environment.

permanent set See **deformation, permanent set.**

permeability The ability of a barrier to allow the passage or diffusion of a gas, vapor, liquid, or solid through it without affecting it physically or chemically. See **absorption; aluminum foil; barrier plastic; chromatography, gel; coefficient of gas permeability; coefficient of permeability; diffusion; gasoline tanks; penetrant; surface preparation; test, oxygen gas transmission rate; water-vapor transmission.**

permeation See **chromatography; percolation; specific gravity, apparent.**

permittivity, dielectric See **electrical permittivity.**

permittivity loss factor See **dielectric dissipation factor.**

permittivity, relative The ratio of the electrical capacitance of a material to the capacitance of air. The relative permittivity of most insulating materials varies from 2 to 10 with air having 1. Higher values indicate greater insulating quality. See **electrical capacitance; electrical permittivity; insulation resistance.**

permselectivity, resistance See **membrane; water-vapor transmission.**

peroxide cured XLPE See **extruder wire and cable cross-linking PE with peroxide.**

personal computer (PC) A computer that is low cost, portable, personally controllable, and easy to use. See **computer software; control-system reliability; reliability.**

persorption The adsorption of a substance in pores only slightly wider than the diameter of absorbed molecules of the substance. See **adsorption.**

PET See **polyethylene terephthalate plastic.**

Petlite A Goodyear Tire & Rubber Co. system that is both a plastic and a process for producing foam single-use containers used for food preparation, transportation, storage, and heating. The process closely relates to the crystalline PET method of producing trays and other containers. The system uses inert gas found naturally in the environment as blowing agents, making it ozone friendly. See **foam and blowing agent; ozone; packaging; polychlorofluorocarbon.**

petrochemicals The chemicals made from feedstocks derived from petroleum oil or natural gas. Examples are ethylene, butadiene, most large-scale plastics, and sulfur. Also called *petroleum chemicals* or *petrochemistry.* See **chemical composition and properties of plastic; design, biotechnology; energy and plastic; feedstock; oil and gas; oil, cracking; oil resources limited; plastic; plastic products, raw material to; steel resources, limited.**

petroleum distillation See **pitch.**

petroleum plastic A thermoplastic that is obtained from a variable mixture of unsaturated monomers recovered as byproducts from cracked or distilled petroleum streams. Typical applications include adhesives, printing inks, rubber compounding, and surface coatings.

pH The degree of acidity or alkalinity of a substance. Neutrality is pH 7; acid solutions are less than 7, and alkaline solutions are more than 7. See **acid gas; pH indicator.**

pharmaceutical See **coating, microencapsulation; drug application; medical-device packaging clarity; medical seal and closure.**

phase A particular visible appearance or state that is not necessarily a separable portion of a system but occurs in a regularly recurring cycle of changes. It implies a change that is either literal or figurative.

phase angle See **dielectric-phase angle.**

phase change The transition from one physical state to another, such as gas to liquid, liquid to solid, gas to solid, or vice versa. See **chemical reaction; exotherm.**

phase transformation See **thermodynamic phase transformation.**

pH buffer action The resistance of a solution to change pH.

phenol A class of aromatic organic compounds in which one or more hydroxy groups are attached directly to the benzene ring. It is used in producing plastics such as epoxy (bisphenol-A), phenolic, and nylon-6. See **chemical benzene ring; test, phenol Gibbs indophenol.**

phenol formaldehyde plastic See **phenolic plastic; resitol; test, phenol Gibbs indophenol.**

phenolic cement A phenolic-based adhesive. See **adhesive.**

phenolic plastic A plastic that is produced by the condensation of phenol with formaldehyde. These thermosets can be used in high-temperature products that include various fillers and reinforcements providing a very broad range of properties as well as a wide range of cost. Formulations can be prepared that do or do not let off gases during curing. The PF plastics are soluble and heat curable.

Novolak plastics require a bifunctional cross-linking agent, usually diamine, to cure. Uncured or partially cured plastics are used as coatings, adhesives, potting compounds, and binders. They have good dielectric properties, hardness, thermal stability, rigidity, and compressive strength but poor resistance to bases and oxidizers and dark colors after curing. Also called *phenol formaldehyde plastic* or *PF*. See **A-B-C stages; asbestos; Baekeland, Leo Hendrik; coating material; cresol; laminate; mold breathing; reinforced plastic; resitol.**

phenolic plastic foam See **foamed ground aircraft arrester.**

phenolic plastic, resorcinol modified A phenolic plastic that has been modified by the addition of resorcinol. This thermoset is commonly used in applications such as those requiring good heat resistance, dimensional stability, and creep resistance.

phenolsilane plastic A thermoset copolymer of silicone and phenolic plastics in solution form.

phenoxy plastic A thermoplastic polyester plastic that is based on bisphenol-A and epichlorohydrin and provides special high-performance properties. It is used in moldings, adhesives, and coatings.

pH indicator A substance, usually in sheet form, that changes color when the pH of the liquid medium is changed. See **pH.**

phlogopite See **reinforcement, disk.**

phonographic record Since the early part of the twentieth century, various manufacturing compression-type techniques have been used to prepare the vinyl compound for molding records into a finished vinyl disc. Extruders or injection-molding systems produce approximate 5 in. (13 cm) squares called biscuits. They are stored until used by heating them and in turn put into a stamping press. Systems also have the hot melted biscuit from a plasticator going directly to the press. This market has been dropping while cassette tapes have somewhat leveled off, and compact disc sales are rising extremely fast in the recording industry as well as others. See **compact disc; recording media.**

phosgene A hazardous gas of carbon monoxide plus chlorine gas. See **carbon tetrachloride; hazard.**

phosphorescence **1.** The luminescence that persists after removal of the exciting source. Also called *afterglow*. See **afterglow; color, special-effect; fluorescence; luminescent pigment; zinc sulphide. 2.** A luminescence whose decay, on removal of the exciting source, is temperature-sensitive.

phosphorous-base flame retardant A substance that reduces smoke obscuration and corrosiveness to create opportunities for phosphorous additives as alternatives or complements to the more standard halogenated compounds. New-generation products are designed to overcome some of their previous drawbacks. Smoke-toxicity concerns about brominated and chlorinated flame-retardants emerged in the 1980s as one of the key factors driving the development of nonhalogenated flame-retardants, including phosphorous types. In many ways, smoke toxicity is the least important issue, as everything burned releases some toxics. Instead, two other issues are more important: acid corrosivity in smoke that results from halogenated flame retardants and can affect electrical systems, and smoke density that obscures vision, as smoke with halogens is much heavier than that with phosphorus-based materials.

Phosphorous-based flame-retardants are not without their drawbacks, which depend on the type of additive and the application in which it is used. Most common problems are with thermal stability, plasticization, large particle size, blooming, and migration problems (that can cause cracking and crazing in parts under stress), and cost. A key limiting factor is that many phosphorous flame retardants decompose or volatilize above 230°C (450°F). An exception is red phosphorous, which can be processed above 230°C. Although thermal stability is not necessarily a problem in PE, PP, or TSs like epoxies or polyesters, it is a problem with higher-temperature plastics. However, there is a realm of phosphorous technology that has not been touched that allows retardants to operate above at least 250°C (480°F). See **additive; bloom; cracking; crazing; flame retardant; migration; plasticizer; smoke.**

photochemical hole-burning spectroscopy (PHB) A tool for ultra-high-density optical memory and a fruitful spectroscopic method of detecting properties of matrix plastics. Various kinds of materials have been used for establishing the relationship between PHB phenomena and properties of materials. As an example, dye molecules in amorphous plastic systems have been used because of their high-quantum yield and good processability. See **amorphous plastic.**

photochemical reciprocity law The statement that in a photochemical reaction a constant effect is produced if the product of time and radiant power is a constant.

photochemistry The absorption of light by plastics can produce noticeable physical, mechanical, and chemical changes. Photodegradation and photoxidation can severally limit the usefulness of certain plastics that are not treated. See **antioxidant agent; biodegradable versus photodegradable; degradation.**

photochromic Reversible light sensitivity; darkening with increased intensity and fading with decreased intensity.

photoconductive plastic A plastic that has an increase of conductivity caused by radiation. See **plastic conductivity.**

photodegradable Able to decompose in an environment of ultraviolet radiation within a time period, such as one year, through physical processes into nontoxic carbonaceous soil, water, and carbon dioxide. See **biodegradable versus photodegradable; decomposition; degradable.**

photodegradation See **biodegradable versus photodegradable; decomposition; photooxidation.**

photoelasticity The birefringence that occurs in a transparent material when it is subjected to stress. The birefringence occurs when the material becomes anisotropic due to the microorientation of the molecules under stress. The photoelastic effect is especially useful in the analysis of residual stress and orientation of transparent plastic products by observing them in polarized light. If white light is used, then a series of colored fringes is observed, whose density depends on the amount of stress or orientation, which interferes with two out-of-phase propagating light rays. For nonchromatic light, a series of light and dark fringes are observed. See **birefringence; polariscope; stroboscope; test, nondestructive stress-strain measurement, brittle lacquer technique.**

photoelastic stress analysis See **test, nondestructive photoelastic stress-analysis.**

photoengraving See **printing, photoengraving.**

photoetching tool A tool used to surface treat molds that in turn produce products with a pattern or textured surface. Patterns range from leather or wood grain to line patterns with varying directions and depths. The required pattern is transferred to the mold by a photographic process. The pattern is then etched to the required depth by the application of an appropriate acid, under closely controlled conditions. It can be performed either on complete tools or molds or on any specific areas. Factors that influence results on the different tool steels (H13, 420, etc.) are (1) grades and annealing and hardening conditions; (2) flame hardening, welding, or EDM; (3) grain flow direction of the tool steel; (4) variations in tool steel and cleanliness; and (5) material size. If nitriding is to be used, it must be done after etching. Flame hardening prior to etching should be avoided since the pattern will be etched differently in the flame-hardened zone. Welded steel can usually be etched if the same steel is used in the weld. Poor etching results in surfaces that are marred by residual traces of spark machining, grind, or polish surfaces. Steels with a clean microstructure and low sulfur content give the most accurate and consistent pattern. See **chemical etching; iron; machining; machining, photochemical; metal; mold cavity, etched; steel; surface treatment; texturizing.**

photolysis See **molecule photolysis.**

photooxidation See **biodegradable versus photodegradable; degradable; ultraviolet absorber.**

photon See **radiation, photon.**

photooxidation The photodegradation that occurs in the presence of oxygen. Since photodegradation is frequently a free-radical process, oxygen will also participate, accelerating the degradation process (mainly chain scissions) by promoting chain branching via hydroperoxide group formation and causing the incorporation of oxygen-containing groups into the plastic. It is a main source of weathering problems with plastics and is alleviated by the use of ultraviolet stabilizers. See **degradation; ultraviolet absorber.**

photoplotter See **artwork, photoplotter.**

photopolymer Any of a class of light-sensitive plastics that undergo a spontaneous and permanent change in physical properties on exposure to light. It is used in printing, creating lithography plates for photographic prints, and microfilm copying. Light causes further polymerization and cross-linking, resulting in degradation and in providing the printed matter. For example, esters of polyvinyl alcohol when cross-linked become insoluble, whereas the unexposed portions of the plastic remain soluble. See **laser sintering, selective; printing, lithographic resist; prototype.**

photopolymerization See **polymerization, photo-.**

phthalate ester See **plasticizer, phthalate ester.**

phthalic See **plasticizer, phthalic.**

phthalic anhydride The most important of the commercially available aromatic anhydrides. Its largest end use is in the manufacture of phthalate ester plasticizers used primarily in PVC plastic; its next largest is for unsaturated polyester plastic; and its third is for alkyd plastic. See **alkyd plastic; polyester plastic, unsaturated; polyvinyl chloride plastic.**

physical property A characteristic of materials that pertains to the interaction of materials with various forms of energy and with other forms of matter. In essence, they pertain to the science of physics. They can usually be measured without destroying or changing the material's color or density. See **chemical property; electrical property; mechanical property; periodic table; plastic dopant; testing and classification.**

pi **1.** A mathematical term that is usually identified by the Greek letter π and equals 3.141593. **2.** A state that is formed when two electrons are placed in a pi-bonding molecular orbital. See **mathematical equation.**

pica See **printing pica.**

pick See **fiber pick.**

picture framing See **paint framing defect.**

PID See **temperature proportional-integral derivative control algorithm.**

piezoelectric effect The slight deformation that some crystals experience when voltage gradients are applied in particular directions and, conversely, the electrical change that appears when some crystals are deformed. Certain materials change dimensions when voltage is applied or produce voltage (electrical potential) when deformed. It is used to convert mechanical energy into electrical energy and vice versa. This principle is used to control systems in extruder dies, gauges, transducers, and acoustical sensors.

A piezoelectric plastic spontaneously produces an electric discharge when mechanically stressed or develops a mechanical response when an electric field is applied. For example, polyvinylidene fluoride plastic spontaneously gives an electric charge when mechanically stressed or develops a mechanical response when an electric field is applied. The material's structures are symmetrical so that their centers of positive and negative changes are not coincident. As a result the polarity is sensitive to pressure changes that change the dipole distance and the polarization. See **electrical conductivity; polyvinylidene**

fluoride plastic; sensor, piezoelectric; transducer; welding, ultrasonic.

pigment An additive that alters the appearance of a material by selective absorption or scattering of light. Pigments retain a crystal or particle structure throughout the coloration process and are essentially physically and chemically unaffected by the vehicle or substance in which they are incorporated. Usually they are insoluble compounds and are dispersed in vehicles or substances for application. Hundreds of natural organic or synthetic inorganic coloring agents include pigments of metallic oxides, sulfides, and other salts that impart heat and light stability, weather resistance, color, and migration resistance. Other functional applications of pigments include imparting corrosion or heat resistance, antifouling capability, rubber acceleration activation, and reinforcement. Over $7 billion or 4.6 million metric tons of pigments are used worldwide in paints and coatings, plastics, and construction materials. Other markets include paper, ceramics, inks, textiles, glass, food, and cosmetics. Major change is occurring to meet environmental requirements where heavy-metal-containing pigments are being phased out. Examples of the more acceptable types include waterborne coatings, powder coatings, and radiation curable inks and coatings. See **antimony trioxide; bronzing; cadmium; calcium carbonate; carbon black, animal; channel black; chinese white; coating, antifouling; colorant; color, special-effect; crocking; cuprous oxide; dye; extender; fixing agent; iron oxide pigment; lamp black; titanium dioxide; zinc gray; zinc oxide.**

pigmented A plastic that has colored organic or inorganic pigments added to it after it has been fabricated into a product.

pigmented color dispersion Coloring materials that have been ground and mixed in a thick liquid that is compatible with the plastic system in which it will be used. When added to the plastic, the pigmented dispersions give it color.

pigment, electrical-grade See **zirconium oxide.**

pigment, extended An organic pigment that has been diluted with an extender, such as alumina trihydrate or calcium carbonate. See **alumina trihydrate; calcium carbonate; extender.**

pigment, fluorescent A colorant additive that seems to possess a glow of its own. By absorbing unwanted wavelengths of light and converting them into light of desired wavelengths, colors seem to possess an actual glow of their own. Fluorescent whitening agents absorb near ultraviolet and reemits the power as visible light (violet-blue), thereby causing a whiter appearance when added to a yellowish-white plastic. See **color, special-effect; fluorescence; optical brightener agent; yellowing.**

pigment, inert An additive that does not react with any component of materials. See **additive.**

pigment, inorganic A pigment that is a naturally occurring or synthetically produced inorganic material. Included are titanium dioxides, iron oxides, lead chromes, and cadmiums. See **organic; organic, in-; pigment, organic.**

pigment, luminous A phosphorous pigment that causes finished products to glow in the dark. See **luminance.**

pigment, metal chelate A metallic pigment that is based on a chelated metal. It gives heat and solvent resistance.

pigment, metal-free A monoazo (toluidine red, arylamide, etc.), disazo (dichlor benzidene etc.), or polyazo organic pigment that is free of metals, sulphonic, and carboxylic acid groups.

pigment, metallic A type of pigment that generally is made of thin opaque flakes of aluminum or copper alloy flakes known as bronze pigments. They produce unusual metallic effects. They are made by ball milling either a disintegrated foil or a rough metal powder and then polishing to obtain a flat, brilliant surface on each particle. Added to plastics, they produce unusual silvery and other attractive metallike effects. See **color, special-effect; mill, ball.**

pigment, metal-toner An organic pigment that is made from heavy-metal salts of sparingly water-soluble azo dyes prepared without a substrate. Because of their low solvent solubility, toners do not migrate or chalk and have the added advantage of low cost. They are used in both thermoplastic and thermoset plastics.

pigment, mineral-black A pigment that is made by grinding or heating slate, shale, or coal.

pigment, organic A pigment that is synthesized from organic raw materials but that does not occur in nature. These pigments provide an extensive range of bright and often transparent colors of high tinctorial strength and are generally more resistant to chemicals but less heat and solvent stable than inorganic pigments. See **inorganic; organic; pigment, inorganic.**

pigment, pearlescent A class of pigments with transparent crystals of high refractive index. Depending on their composition, such pigments improve the surface gloss of a plastic or add brilliant highlights. See **color, special-effect.**

pigment, reinforcing A dual-purpose pigment that besides coloring, improves properties. Carbon black is a typical example. See **carbon black.**

pigment, rouge A powder consisting of red oxide that is used as a pigment and for polishing. See **polish.**

pigment undertone The color of a thin layer of pigment-vehicle mixture applied on a white background.

pigment, UV absorber See **carbon black; zinc oxide.**

pigment, Venetian red A pigment with a true red hue that contains 15 to 40% ferric oxide and 60 to 80% calcium sulfate.

pigment, white See **bottle, opaque milk.**

pilot plant A trial assembly of a small-scale processing operation that is an intermediate between a laboratory experiment and full-scale production plant operation.

pimple An imperfection, such as a small protuberance of varied shape, on the surface of a product. See **defect.**
pinch-draw See **roller, pinch-draw.**
pinch-off A device that seals a melt structure. It usually refers to the excess material that can form during pinch-off requiring separation of the excess plastic from the processed part. See **blow molding, extruder, pinch-off; recycling.**
pinch roll See **nip.**
pin ejection See **mold ejector.**
pin hole An undesirable, very small hole or cavity that penetrates the surface of a molded product, plastic coating, or film. See **paint; powder coating.**
pinhole-free coating See **parylene plastic; xylylene plastic.**
pipe A hollow cylinder in which the wall thickness is usually small when compared to the diameter and in which the inside and outside walls are essentially concentric. Thermoplastic (usually unreinforced) and thermoset reinforced-plastic products are produced. See **design pipe; extruded pipe and tubing design; extruder post-forming; extruder pipe and tubing; extruder profile; joining, butt-fusion; reinforced plastic pipe; sewer rehabilitation; underground pipe.**
pipe bell end The enlarged portion of a pipe that resembles the socket portion of a fitting and that is intended to be used to make a joint by heat or adhesion.
pipe connection See **orientation and heat-shrinkability.**
pipe conveying See **conveying, pneumatic; energy conservation; material handling.**
pipe, corrugated See **design, corrugated.**
pipe, deteriorating Groundwater contamination from deteriorating steel sewer pipes poses a risk to a clean water supply. An efficient way to solve this problem is to insert PVC coiled pipe inside the steel pipe. Rigid PVC pipe is heated and coiled like a fire hose so that it can be transported to an installation site. On site, the pipe is heated, unrolled, and guided through a manhole (pulled by a cable, etc.) and through the interior of the damaged pipe. Pressure and steam are then used to expand the pipe so that it hugs the interior of the deteriorated pipe, sealing any cracks and proving a new, corrosion-free transport for sewage. Even though soil conditions and earth movements continue to damage the steel pipe, the "fold and form" PVC interior layer remains intact. See **polyvinyl chloride plastic; safety; sewer rehabilitation; underground pipe.**
pipe diameter standard See **deviation ratio, standard.**
pipe, geothermal Underground heating and cooling pipe systems, when compared to conventional systems, are more than three times as efficient and have about 20% lower maintenance costs. Annual heating and cooling in homes can be reduced up to 40%. The system consists of an indoor heat pump and a buried pipe network, often over 150 m of HDPE. The pump transfers heat from the geothermal underground wells to a building (home, etc.) in the winter and removes the heat from the building in summer. One-piece U-bends made from HDPE are attached at the plastic fabricating plant providing high-quality welds and reduced costs for labor. A special fitting made from HDPE allows the installer to provide monolithic material throughout without fusing the pipe lengths. HDPE's durability, chemical resistance, stress-cracking resistance, and other characteristics permit a typical life of over 50 years. See **extruder pipe and tubing; polyethylene plastic, high-density; underground pipe.**
pipe, liquid oxygen compatibility See **polyarylene ether phosphine oxide plastic.**
pipe market Thermoplastic pipe has been used since the 1930s and now respresents at least 30% of the dollar share of the pipe market compared to other materials (iron/steel at 45%, copper at 12%, concrete at 8%, aluminum at 4%). The major plastics used are HDPE, PVC, and PP. The main application for plastic pipes is for gas distribution and they also are used in industrial mining, oil and gas production, and water transport. Although thermoset plastic pipe represents a small portion of the market, it is a product of choice for many special applications. Corrosion resistance, toughness, and strength contribute to its growing acceptance. See **extruder pipe and tubing; reinforced plastic pipe.**
pipe toe-in A small reduction of the outside diameter at the cut end of a length of pipe.
pit The formation of open-faced craters, air bubbles, or voids on a parts surface. See **mold-cavity coating; spalling.**
pitch **1.** The high-molecular-weight residue from the destructive distillation of petroleum and coal products. It is used as a base material for the manufacture of high-modulus carbon fibers. See **fiber, carbon; graphitization; mesophase; polyacrylonitrile plastic. 2.** See **screw flight pitch.**
planar See **directional property, planar.**
plane angle See **radian.**
planned obsolescence A design that ensures that within a certain period a product will require repair or replacement.
planning See **computer-aided process planning.**
plant certification See **ISO-14000 certification.**
plant control Modern central control and management systems are called by different names, such as supervisory control, distributed control, CAD, CAM, CAE, CIM, and so on. These systems can maximize plant layout efficiency by monitoring and controlling all operating parameters for basic machines as well as all upstream through downstream equipment. The systems receive inputs on all parameters and can issue instructions to each machine to ensure efficient and profitable operation.

For these systems to operate efficiently, they must be completely integrated into all plant operations. Start-up through shut-down procedures for all equipment, limits, and control instructions must be suited to meeting product performance requirements at the lowest processing cost. Training is essential to operating and setting up the equipment and establishing and following safety procedures. See **computer control; control actuator; data-management system; designing plant layout via computer; fabricating process; productivity.**

plant cost See **economic efficiency and profitability.**

plant environment Plants can have hostile processing environments for equipment and particularly instrumentation. High process temperatures, abrasive and corrosive materials, and the mishandling of equipment are examples that can present problems. See **noise; transducer calibration.**

plant operation Plant design varies according to the type and magnitude of production, space available, availability of labor, and marketing conditions. Proper planning is required to set up and operate the production line, which starts with receiving and handling plastic material, ends with the product's proper packaging, and interrelates materials, process, and products. See **barcode; computer electronic document and retrieval system; fabricating process type; processing; production data acquisition.**

plant safety Safety requirements are available from equipment suppliers who understand how to handle plastics. They include safe start-ups and the location of safety devices. Processing plastics usually generates significant force and heat, and its equipment must be treated with understanding and respect. See **safety.**

plasma A high-temperature ionized gas that is composed of electrons and positive ions. It is a partially or totally ionized gas or vapor. See **electron; ion.**

plasma arc treatment In adhesive and solvent bonding and printing, a method for treating the surfaces of parts prior to bonding, in which an electrical current between two electrodes in a gas at low pressure excites the gas particles, producing free radicals. Contaminants are stripped from the surfaces of the parts, and wettability is increased by reduction of the contact angle. See **adhesive, solvent; printing; surface treatment.**

plasma treatment A process for modifying plastic surfaces that is more stable and reliable than conventional corona discharge processes. See **adhesive; electrical corona discharge treatment; electronic treatment; joining; plasma arc treatment; surface treatment.**

plaster of Paris A material that is made by the complete or partial dehydration of gypsum. It is used as a plastic filler and in the production of patterns and molds. Also called *calcined gypsum.* See **modeling.**

plastic One of a large and varied group of about 17,000 materials. Plastics usually consist of, or contain as an essential ingredient, an organic substance of high molecular weight. Most are produced synthetically; very few occur in nature. Some plastics contain inorganic material. The term *plastic* comes from the Greek word "to form," and plastics provide all kinds of (simple to extremely complex) shapes. Practically all plastics at some stage in their manufacture or fabrication can be formed into various shapes that can range from being extremely flexible (rubbery/elastomeric) to extremely hard (high performance properties). Plastics are broadly integrated into almost all market areas. The use of a virtually endless array of additives, colorants, reinforcements, and fillers permits compounding, and raw-material suppliers and fabricators can impart specific qualities to raw materials that expand their opportunities. Compounding relies on the polymerization chemistry to combine a base plastic with modifiers, additives, and other plastics to develop new plastics. See **additive; design shape; extender; filler; molecular weight; plastic products, raw material to; recycling and sense; reinforcement; stabilizer.**

The terms *plastics, resins,* and *polymers* are somewhat synonymous. *Polymers* and *resins* usually denote the basic material. The term *plastics* pertains to those containing additives, fillers, or reinforcements as well as the basic materials. Total sales for plastic products and plastic materials are now well over $275 billion per year, making plastics the fourth largest industry in the United States. Machinery sales (all types) in the plastic industry are estimated to be above $3 billion per year. See **composite; design, material optimization; plastic industry size; polymer; reinforced plastic.**

Polymers are high-molecular-weight organic compounds of synthetic or natural origin that consist of molecules characterized by the repetition (neglecting ends, branch junctions, and other minor irregularities) of one or more types of monomeric units. A repeated small unit, the *mer,* such as ethylene, represents its structure. Practically all of these polymers use certain types of additives to perform properly during fabrication and in service. Plastics can be either thermoplastic or thermoset plastics. See **amorphous plastic; chemistry, inorganic; chemistry, organic; crystalline plastic; mer; semicrystalline plastic; synthetic; thermoplastic; thermoset plastic.**

The term *plastic* also refers to a material that has the physical characteristics of plasticity and toughness. See **ductility; plasticity; toughness.**

plastic, advanced A high-performance material. Also called *advanced reinforced plastic* or *advanced plastic composite.* See **engineering plastic; reinforced plastic, advanced.**

plastic, air-inhibited A plastic that is inhibited or tacky in the presence of air.

plastic, air-noninhibited A plastic that is not inhibited or tacky in the presence of air. A surface coating can be used to make a plastic air noninhibited.

plastic, amorphous See **amorphous plastic; crystalline plastic; semicrystalline plastic.**

plastic and die-cast metal Plastics have several advantages over die cast metals in many applications, including light weight, resistance to corrosion and chemicals, design flexibility, and lower finishing costs. Die-cast metals, however, have superior temperature and creep resistance when compared to certain commodity-type plastics, although some engineering plastics outperform them. See **die-casting alloy.**

plastic and feedstock Most plastics are produced from petroleum, natural gas, or coal. The resulting plastics have various properties, depending on the manufacturing process and additives, fillers, and reinforcements included. In turn, these plastics are fabricated into many different varieties of products. See **design, biotechnology; feedstock; oil and gas; oil, cracking; ore; petrochemicals; plastic; plastic products, raw material to; polymerization.**

plastic and food Plastics play an important role in food production. For example, (1) film helps protect crops, produce early harvests, increase yields, and promote energy conservation in greenhouses; (2) weather-resistant plastic coatings and linings for silos and bins permit safe storage of foodstuff; (3) irrigation using plastic tubing can provide water savings of 33 to 50% over other systems, while reducing herbicide use and increasing yields; (4) safe, convenient plastic packaging maintains product freshness and protects against contamination; and (5) plastic packaging increasingly is being called on to provide shelf-stable food supplies in the industrial world and relief efforts. See **packaging, food.**

plastic and forensic science See **legal matter: forensic science and plastic.**

plastic and lumber Recycled plastics are processed as commingled plastic, polyethylene plastic, and polypropylene plastic to produce products that are competitive to wood lumber on land and in the water. They are principally extruded but also injection molded. House decks and boat docks are product examples. Plastic lumber is maintenance-free for at least half a century, as opposed to 15 years for treated wood and 5 years for untreated wood. See **extruder; fire and plastic; injection molding, nonplastic; recycling; recycling commingled plastic; waste; wood, compreg; wood-plastic impregnated.**

plastic and milk See **casein plastic.**

plastic and pollution Plastics are generally not naturally biodegradable, which is considered an important advantage. Although postconsumer waste is a visual annoyance, plastics contribute only about 1wt% of the solid-waste stream. See **chemical reclamation; incineration; plastic, long-life; pollution; recycling; recycling and sense; recycling waste; waste.**

plastic and the future Plastics, a little over a century old (1880s), are the first new commercial material that has become available in more than 3,000 years. Few, if any, other materials worldwide have had such a lasting impact on virtually all spheres of life for over a century, and new developments continue to evolve in materials, processes, and products. The process science and technology area involves factors such as fabricating processes, materials, process controls, production tools, energy reductions, and waste reduction. The fabricating and operations area involves factors such as the focus on customers, production capabilities, building new plants, supplier relations, and global operations with interrelationships. See **design, biotechnology; design success; designing with plastic tailor-made models; integrated circuit, plastic; Japanese workmanship; military market; plastic consumption; plastic failure or success; plastic growth; plastic history; plastic industry size; plastic, long-life; plastic myth and fact; plastics and electronics toys; recycling and sense; structure; thermoflow plastic.**

plastic and water conservation Population growth and exploitation of resources have made water increasingly scarce, costly, or contaminated in many parts of the world, including the United States. Some solutions to these problems involve plastics: (1) plastic reservoir covers and liners help prevent water loss by evaporation or leakage in large-volume storage or delivery systems; (2) plastic piping and fittings make irrigation systems lower cost, simpler, and more efficient; (3) plastic pipe is steadily replacing metal in plumbing applications; lead-free plastic plumbing now distributes potable water in over 35% of U.S. households and businesses and is used in over 95% of irrigation systems; (4) "slip-in" plastic liners have brought new life to aging aqueducts and water mains since the 1960s using TP (PVC, PE, etc.); liners are installed without service interruptions; (5) plastics are increasingly the material of choice for storage tanks to protect groundwater from chemicals or corrosive liquids (gasoline, etc.); and (6) major tree-planting programs in developing nations use plastics to aid in growing and transporting millions of seeds. The amount of water on earth has basically remained the same for centuries. It recycles itself from earth, into the sky, and back to earth. The real change is that more people live on earth. See **ecology; vinyl seagoing bag; water.**

plasticate To impart flexibility in a plastic through the input of heat or mechanical work as in the plasticating in extruders or injection-molding machines.

plastication The condition of a plastic material when it has been softened for use in a melt-processing operation. See **plasticizer; screw plasticator frictional heat.**

plastication, pre- Premelting molding material in a separate plasticator (chamber) and then transferring the melt to the main processing machine, such as the feeder on a cylinder (injection-molding or extruder machine). See **compression molding, screw preplasticator.**

plasticator An important component in a melting process that uses a screw and barrel in different machines (extruders, injection molding, blow molding, etc.). If the proper screw design is not used, products may not meet or maximize their performance or meet their cost requirements. The hard steel shaft screws have helical flights, which rotate within a barrel to mechanically process and advance (pump) the plastic. General-purpose and dedicated screws are used. The type of screw used depends on the plastic material to be processed. See **barrel; barrel,**

extruder and injection-molding; concentricity; extruder barrel; screw; screw length-to-diameter ratio; screw plasticator; shear heating.

plasticator safety If you pack plastic into a steel pipe without air, plug both ends of the pipe, and heat it, you have made a bomb. The damage it can cause depends on the amount of heat applied, which produces internal pressure prior to the pipe or plugs letting go. This situation relates to a plasticator, even though it is extremely rare that an explosion occurs. To eliminate any potential problem, proper startup procedures are used. If all the plastic between the screw and barrel is not melted, a frozen plastic plug could form. Safety devices used include a release plug in the barrel wall or bolts attached to components and the barrel. These devices are designed to be released when pressures reach specified amounts depending on the pressure a particular piece of processing equipment is operating under. See **barrel fail-safe rupture disc; barrel-venting safety; safety.**

plasticator wobble A barrel of a plasticator that wobbles when the screw is rotating is misaligned. It could be an alignment deficiency between the transmission, feed block, or barrel. This should be investigated immediately as it can result in a high-wear situation, screw breakage, heater creep, or shutdown of the machine.

plastic bag See **packaging, grocery-bag; vinyl seagoing bag.**

plastic chemical structure See **amorphous plastic; crystalline plastic; fastener, nonmechanical; molecular-arrangement structure; molecular microstructure; orientation; semicrystalline plastic; x-ray microscope.**

plastic-concrete composite A composite that has been used since at least the 1940s to improve the mechanical and durability properties of concrete, usually using portland cement. Techniques used include (1) impregnating concrete with plastic using a liquid monomer that is polymerized in situ, (2) adding latex in the mix of cement aggregate and water, usually called polymer portland concrete, and (3) adding water-soluble plastic in a cement-water mix to eliminate microscopic defects owing to poor particle packing and entrapped air. When compared to concrete, the composite provides reduced weight, increased comprehensive strength (tensile, flexural, compression, modulus, etc.), reduced water permeability and absorption, increased abrasion resistance, dampened vibration (of presses and other machine tools), color retention, and resistance to aggressive/corrosive environments such as rain water, freeze-thaw cycles, or seawater. However, cost increases. Plastics used include thermoset polyester, acrylic, phenolic, epoxy, and PE. Processes include casting, impregnation, extrusion, and compression molding. Plastic contents range from 5 to 30wt% depending on type, application, and ability to meet coefficient of expansion requirement. Mixes can be produced with nonshrink characteristics. Filling cracks in cement constructions, such as building basement wall and foundation support, eliminates water seepage. Other applications include patching and repairing bridges, surface drain systems, utility boxes, and poles. See **coating, steel-rod; composite; concrete, reinforced; impregnation.**

plastic conductivity Most plastics do not conduct thermal or electrical energy, but some are conductive or can be made conductive by adding appropriate additives or fillers. See **conduction, heat; electrical conductivity; electromagnetic interference; molecular conductivity; photoconductive plastic; plastic dopant; plastic, electrically conductive; test, conductivity; thermal conductivity.**

plastic consumption Worldwide total plastics consumption is at least 150 million tons (340 billion lb) with about 90% thermoplastics and 10% thermoset plastics. U.S. consumption is about one-third of the world total. There are about 17,000 different type plastic materials worldwide, but most are not used in large quantities. A couple dozen types represent certain families of plastics. Within those families are the five major thermoplastic types that consume about 80wt% of all thermoplastics (18% low-density polyethylene, 17% polyvinyl chloride, 12% high-density polyethylene, 16% polypropylene, 8% polystyrene). Each family has literally thousands of different formulated compounds. It is estimated that 36wt% is used by extruders, 32% in injection molding, 10% in blow molding, 8% in calendering, 5% in coating, 3% in compression molding, and others at 3%. Thermoforming, which is the fourth major process used, consumes about 30% of the extruded sheet and film that principally goes into packaging. At least 65wt% of all plastics require some type of compounding and go through compounding extruders before going through equipment to produce products, usually twin-screw extruders. It is estimated that in the United States there are about 18,000 extruders, 80,000 injection-molding machines, and 6,000 blow-molding machines, which produce about one-third of the world's plastic products. The plastic industry is the United States's fourth-largest industry and is growing at three to four times faster than that of other industries. Total sales for all fabricated products are estimated to be approaching $275 billion per year. See **blow-molding market; building and construction; calender; coating; compounding; compression molding; energy consumption; extruder; fabricating employment; fabricating process type; foamed plastic market; gross domestic product; injection-molding machine sales; market; material handling; packaging; plastic growth; plastic industry size; plastic, long-life; plastic markets, product and material; plastic material type; plastic processing; plastic products, raw material to; thermoforming; wood.**

plastic consumption worldwide by type See **Table 1, World Consumption of Plastics in the year 2000.**

plastic consumption by volume/weight. See **Figure 6, World Consumption of Plastics by Volume; Figure 7, World Consumption of Plastics by Weight.**

plastic, contact-pressure A liquid plastic, such as a thermoset polyester, that thickens or initiates polymerization on heating and that when used during certain processes, such as reinforced-plastic bag molding, requires little or no fabricating pressure. Also called *contact resins* or *contact plastics*. See **polyester plastic, thermoset; reinforced-plastic bag molding.**

plastic content The amount of plastic in a compound, reinforced plastic, laminate, or any other material containing additives, fillers, or reinforcements expressed as a percentage of total weight or volume.

plastic dispersion Finely divided particles in suspension or distribution in another substance. See **colloidal; equilibrium centrifugation; organosol; plastisol; plastisol, modified; polyvinyl chloride dispersion plastic.**

plastic dopant **1.** A material that is added to a plastic to change a physical property. **2.** A chemical element that is added in trace amounts in a semiconductor crystal to establish its conductivity type and resistivity. See **dopant; plastic conductivity; plastic, electrically conductive.**

plastic drying Plastic materials, either in virgin forms (such as pellets and granules) or regrind materials, are subject to contamination by moisture. When moisture is present during molding, it tends to cause defects in the molded part, such as irregular moldings, splay marks, brittleness, lower physical and mechanical properties, nozzle drool between molding shots, foamy melt, bubbles in parts, poor shot control, and sinks. See **drying operation, hygroscopic plastic; plastic, hygroscopic; venting, feeder.**

plastic, electrically conductive **1.** Two distinct groups of ionically conductive and electronically conductive plastics. An example of an ionical type is polyethylene oxide containing $LiClO_4$, which is used as a solid-phase electrolyte in batteries. Electronic types can be further divided into intrinsically conductive plastics (ICP), inherently dissipative plastic (IDP), and filled plastics that are extensively used in electromagnetic interference shielding meeting different electrical requirements. As the name implies, the conductivity of ICPs arises without an addition of conductive fillers. They are plastics with strong electrical conductivity. The IDPs exhibit weaker electrical properties than ICPs. When compounded with other plastics, they can impart antistatic properties to molded products. The IDP compounds generally have lower ionic and metallic contaminant levels than conductive compounds containing traditional additives. They are preferred for static protective packaging of sensitive products. See **conductivity, electrical; electromagnetic interference; piezoelectric plastic; plastic conductivity; test, conductivity.** **2.** A plastic with certain chemical structures that display unusual electronic conductivity properties, such as low-energy optical transitions, low ionization potentials, and high electron affinities. The result is a class of plastics that can be oxidized and reduced more easily and more reversibly than conventional plastics. Charged transfer agents (dopants) affect this oxidation or reduction and in doing so convert an insulating plastic to a conductive plastic with near metallic conductivity in many cases. See **dopant; plastic conductivity.**

plastic employment See **fabricating employment; plastic consumption.**

plastic, engineering See **commodity plastic; engineering plastic.**

plastic equipment See **auxiliary equipment; fabricating processing type; plastic consumption.**

plastic, ethnic A family of plastics with a basic monomer structure. A series of plastics with greatly different characteristics can be obtained by altering a monomer structure by removing a hydrogen atom and substituting another functional atom or group of atoms.

plastic failure or success It is determined by three fundamental factors: material, design, and processing. Combined they determine how a product responds to service conditions. See **defect; design-failure theory; design success; fabricating; plastic material selection; plastic processing; plastic product failure; problems and solutions.**

plastic feed form Forms such as pellets, granules, powders, flakes, and recycled plastics. The usual types are in solid form, but liquid forms are available for certain plastics and processes. If material is fed as different forms or different shapes of the same product, then feeding and processing problems could easily develop. In terms of output efficiency, generally spherical granules of about 3 mm (0.118 in. diameter) are the most efficient, with the worst being fine powder, except with certain additives or processes. Safety precautions are to be taken to eliminate fires or explosions. Uniformity in size and shape is a target to meet; recycled materials can reduce efficiency or increase cost due to size and shape differentials in addition to their residence time. See **blending; feeder; material; material feeding and blending; plastic types; plastic marriage; plastic material; recycling; residence time; safety.**

plastic finishing See **material tumbling; surface finish; surface treatment.**

plastic foam clamshell See **environment and public opinion.**

plastic form, fill, and seal See **blow molding, extruder blow, fill, and seal; medical packaging; thermoforming, form, fill, and seal.**

plastic, foundry Plastic used in the production of shell molds and foundry cores. See **foundry plastic; foundry shell molding.**

plastic, general-purpose (GP) A material that is suitable for a wide range of processes and applications.

plastic-glass alloy A material developed by Corning, Inc., Corning, NY, with components that have the same glass transition temperature (T_g). These materials consist of special low-melting or "softened" glass with LCP or PEEK plastics. Because the glass phase actually flows along with the plastic during processing, the alloy displays a finely dispersed morphology with isotropic properties. See

alloy/blend; directional property, isotropic; glass transition temperature; morphology.

plastic, granite A material that gives solid durable surfaces with beauty. One class is a mixture of thermoset polyester plastic with alumina trihydrate fillers for installations subjected to uninterrupted usage. Another has acrylic plastic with alumina trihydrate fillers that provide resiliency.

plastic green strength Even though the cure is not complete, the mechanical strength of certain materials allows removal from the mold and handling without tearing or permanent distortion. This characteristic is referred to as the plastic's green strength. See **tensile green strength.**

plastic grout A plastic compound that is used as a filler. It is used to fill or finish a surface or hole. See **closure.**

plastic growth Plastics are among the world's most widely used materials compared with steel, aluminum, rubber, copper, and zinc. Plastic materials surpassed steel and iron on a volume basis in 1983. By about the start of the twenty-first century, plastics are expected to surpass steel on a weight basis. However, these materials represent only up to possibly 3vol% of all materials consumed worldwide. They do not include the two major categories of wood (building, paper, etc.) and construction material (concrete, stone, etc.), which represent about 45vol% worldwide. How about a probable speculation that if wood had never been used in buildings and elsewhere, our regulations on fire and contamination would outlaw its use? See **building and construction; building and construction market; design, biotechnology; plastic and the future; plastic consumption; wood; worldwide population; World of Plastics Reviews: Making Marketing Work.**

plastic, halocarbon A plastic that is based on materials made by the polymerization of monomers composed only of carbon and halogen. See **polymerization.**

plastic handling See **conservation of matter, law of; material handling.**

plastic, heat resistant See **ablative plastic; insulation resistance; temperature properties of plastic.**

plastic, heat-shrinkable See **orientation and heat-shrinkability.**

plastic heat staging The heating of a thermoset plastic premixed compound, such as a prepreg, until the chemical reaction (curing) starts but before the gel point is reached. Staging is often used to reduce plastic flow in subsequent press-molding operations. See **prepreg; reinforced-plastic prepreg; thermoset plastic.**

plastic history The origin of plastics can be dated back many centuries to when natural materials were used as fillers, adhesives, and coatings. Goodyear discovered how to vulcanize (thermoset cross-link curing with sulfur) natural rubber in 1836. In 1851 the first thermoset material, ebonite or hard rubber, was discovered. During the 1850s in England, Parkesine material, a hard, elastic, and waterproof cellulose solution mixture, was developed. By 1868 in the United States, John Wesley Hyatt developed cellulose nitrate plastic. In the United States in 1907, Leo Hendrik Baekeland discovered techniques to produce phenolic plastic. In 1920, Hermann Staudinger developed the theory of the chemical nature of plastic molecules as we now know it. The period from 1930 to 1940 saw the initial commercial development and expansion of today's major thermoplastics (polyethylene, polystyrene, polyvinyl chloride, etc.). There continue to be all kinds of new plastic discoveries and developments. Some of the historical highlights regarding plastics and other related products that influenced the growth of plastics that are included in this book are listed. See **aircraft; aircraft, Gossamer Albatross; aircraft, Solar Challenger; American Standards for Testing; automotive market; Baekeland, Leo Hendrik; barrel history; Boltzmann, Ludwig; casting, acrylic-sheet; cavitation erosion; cellulose nitrate plastic; cement construction; clamping platen, book-opening; Coca-Cola bottle; Coor's beer bottle; composite; concrete; dental amalgam; design, basics-of-flow die; design, pipe; energy and bottles; extruder wire and cable, ram; fiber, boron; gasoline tanks; gear pump; grass, synthetic; heat effect, Gough-Joule; Hyatt, John Wesley; ice, synthetic; injection-molding aircraft canopy; ISO; ketchup bottle; laminate; lens, contact; melamine formaldehyde; mold, preengineered; oil resources, limited; orientation; Parkesine plastic; phonographic record; plastic growth; plastic house; plastic product failure; plastic, smart; Plastics Pioneer Association; polymerization history; printing, Acrobot; radome; rain; rail car; recycling history; reinforced plastic; reinforced-plastic Macro process; Reynold's number; rubber, natural; sampling plan; screw, barrier; screw mixing, pin; sewer rehabilitation; SI; test, NOL ring; shellac; spray-paint coating; Staudinger, Hermann; styrol; tanker truck, reinforced-plastic; telcothene plastic; testing and classification; transducer, magnetostrictive; transfer-molding Shaw pot; triallyl cyanurate; trucks and plastic; tubing; Unipol; Velcro strip; vinyl chloride monomer; vinyl ester plastic; vinyl plastic; vulcanized fiber; wood-plastic impregnated; zipper.**

plastic house For over a century plastic houses, with or without other materials, have been designed and fabricated worldwide in the industrial nations and particularly in the nonindustrial nations. Plastic materials have included reinforced plastics, foamed plastics, extruded plastics, and thermoformed plastics. A few of these houses are reviewed. (1) One of the first relatively all plastic houses was the Monsanto House erected in Disneyland, CA, in 1957. It used U-shaped cantilever (monocoque box girders) glass fiber-thermoset polyester reinforced plastic designed at MIT. After two decades of service subjected to the equivalent of a century of high winds, earthquakes, and family use, it suffered almost no damage or deflection. Conventional techniques for destruction (wrecking ball, etc.) were impossible, so it was sawed into sections for dismantling. (2) The GE living environmental house in Pittsfield, MA, with 3,000 ft^2 (280 m^2) of floor space was opened to the public on October 23, 1989. It features advanced design and building methods, processes, and materials to serve as a laboratory for the entire building industry. It explores the feasibility of widespread use of plastics in construction. The two interior floors reflect the daily living environment of a family of four. The basement contains a 2,500 ft^2 business center, offices, and a display area for prototype models, such as factories to produce highly automated housing systems. (3) Dow Chemical's domed-shaped all-plastic PS foamed-board buildings in Lafayette, IN (1966) used their patented spiral generation technique. Self-supporting domes provided insulation and allowed sections to be cut for doors and windows. (4) Royal Building Systems Ltd., Weston, Ontario, Canada, has been producing PVC extruded walls and erecting homes in different parts of the world. See **building and construction market.**

plastic, hydrocarbon A brittle or gummy material that is prepared by the polymerization of several unsaturated constituents of coal tar, rosin, or petroleum that are composed of carbon and hydrogen only. They are inexpensive and find use in rubber and asphalt formulations and in coating and caulking compositions. See **caulking compound.**

plastic, hygroscopic A material that tends to absorb moisture from the air. These plastics require extra processing steps of drying to produce high-quality parts. Conventional dryers waste energy due to heat losses and the use of cooling water. Innovative dryer designs provide improved efficiency and energy savings by actions such as using heat exchangers and using the energy contents of the warm air that returns from the hopper. See **dehydration; drying operation, hygroscopic plastic; drying operation, nonhygroscopic plastic; hydrolysis; hydrolytic stability; injection-molding venting; venting; water.**

plastic industry Plastic products can be characterized in many different ways, such as impact or tear resistance, flexibility, performance in all kinds of environments, decoration, short (throwaway) to long service life, degradability to nondegradability, virgin or recycled, simple to complex shapes, breathable film, and many other market requirements. See **fabricating employment; plastic consumption; standard industrial classification.**

plastic industry machine sales Worldwide machinery sales (primary and secondary/auxiliary all types) in the plastic industry are estimated to be above $9.0 billion/year. See **blow-molding market; fabricating process type; gross domestic product; injection-molding machine sales; market; World of Plastics Reviews: The Plastics Industry.**

plastic industry size Plastic products are the fourth-largest U.S. manufacturing industry, behind motor vehicles in first place, petroleum refining in second place, and automotive parts in third place. Plastics are followed by computers and their peripherals, meat products, drugs, aircraft and parts, industrial organic chemicals, blast furnaces and basic steel products, beverages, communications equipment, commercial printing, fabricated structural metal products, grain mill products, and dairy products. Plastic materials are in twenty-fourth place. Total sales for the category of plastic products and plastic materials is now well over $275 billion per year. Machinery sales (all types) in the plastic industry are estimated to be above $3 billion per year. See **gross domestic product; plastic consumption; plastic markets, product and material; research and development.**

plastic innovation See **blow-molding innovation; design, biotechnology; design, innovative.**

plastic, inorganic In broad terms, any substance containing a large number of repeated units that involve elements other than carbon connected by any type of chemical bond. See **chemistry, inorganic; chemistry, organic.**

plastic, ion-exchange A cross-linked plastic that forms salts with ions from aqueous solutions. These plastics are used in water softening. See **cross-linking; water softening.**

plastic intermediate load behavior See **creep loading.**

plastic interrelation See **plastic processing.**

plasticity The characteristic of an elastomer manifested by retention of deformation after removal of the deforming stress. See **ductility; plastic; thermoplasticity.**

plasticize **1.** To soften a plastic and make it processable. Some plastics require additives so they can be plasticized. **2.** It is to soften a material usually through the use of heat.

plasticizer A compounding material that is used to enhance the deformability of a plastic. It can increase a material's softness, flexibility, and processability by a solvent or lubricant or by lowering its molecular weight. Plasticizers can lower melt viscosity, improve flow, and increase the low temperature resilience of the material. Most are nonvolatile organic liquids or low-melting-point solids, such as dioctyl phthalate or stearic acid. They have to be nonbleeding, nontoxic, and compatible with the material. Sometimes they provide a dual role as stabilizers or cross-linkers. They are classified in chemical groups such as phthalates, phosphates, glycols, and epoxies. Different plasticizers can be used for different plastics. For example, phthalate plasticizers (dioctyl phthalate, etc.) are extensively used in PVC. Controversies have developed over the environmental impact of plasticizers, but there is little evidence to indicate that phthalates negatively affect the environment. Also called *flexibilizer, primary plasticizer,* or *secondary plasticizer.* See **butyl diglycol carbonate; butyl epoxy stearate; butyl stearate; camphor; chlorinated diphenyl; chlorinated hydrocarbon; citrate plasticizer; coumarone-indene plastic; diluent; dimethyl phthalate; dioctyl phthalate; dioctyl sebacate; epoxide plasticizer; flexibilizer additive; impact modifier; organosol diluent; phosphorous-base flame**

retardant; plastication; plasticizer, phosphate; plasticizer, phthalate ester; plasticizer, phthalic; plasticizer, primary; plasticizer, secondary.

plasticizer and lubricant See **butyl diglycol carbonate.**

plasticizer and migration See **migration and plasticizes; plasticizer, nonmigratory; plasticizer, nontoxic.**

plasticizer and molecular weight See **solubility and molecular weight.**

plasticizer extender A substance that is incompatible with plastics (only slightly miscible) and is used in conjunction with a primary plasticizer as a lower-cost diluent. Also called *secondary plasticizer.* See **extender.**

plasticizer exudation The migration in liquid form of a plasticizer to the surface of a plasticized plastic product.

plasticizer, internal An agent that is incorporated in a plastic during polymerization, as opposed to a plasticizer added to the plastic during compounding. See **compounding; plasticizer.**

plasticizer, iodine value The number (value) of grams of iodine that 100 g of an unsaturated compound will absorb in a given time under certain conditions. It is used to indicate the residual unsaturation in epoxy plasticizers; a low value implies a high degree of saturation. See **saturation.**

plasticizer, nonmigratory A plasticizer that does not pass readily from the elastomeric compound of which it is a part. See **migration and plasticizers.**

plasticizer, nontoxic The U.S. Food and Drug Administration has published in the *Federal Register* a list of plasticizers that are sanctioned, including acetyl tributyl citrate, butyl stearate, dibutyl stearate, diethyl phthalate, and triethyl citrate.

plasticizer, phosphate A main group of plasticizers that are prepared by the action of phosphorous oxychloride and alcohol.

plasticizer, phthalate ester A plasticizer that is produced by the direct action of alcohol on phthalic anhydride. They are a widely used plasticizer; generally characterized by moderate cost, good stability, and good all-around properties.

plasticizer, phthalic A term that was coined from naphthalene, from which phthalic anhydride is made and used principally as a plasticizer for vinyls and cellulose plastics.

plasticizer, polyester A plasticizer that is noted for its permanence and resistance to extraction.

plasticizer, primary A plasticizer that has sufficient affinity to the plastic to be used as the sole plasticizer. Using the secondary plasticizer, when material requirements permit, reduces costs.

plasticizer release See **automotive interior, low-emission plastic.**

plasticizer, secondary A plasticizer that is insufficiently compatible with the plastic material to act on its own and must be mixed with the primary plasticizer. Such secondary materials act as dilutents to the primary plasticizer and are generally used to reduce cost. See **chlorinated hydrocarbon.**

plastic, light-switchable A film that is laminated with plastic interlayers so that when electrical voltage is applied, the liquid-crystal droplets that coat the film align to transmit light, and the window looks like a normal window. Switching off the voltage, the liquid crystals realign randomly, scattering light and turning the window translucent. The window can consist of a lamination of two layers of GE's Lexan sheet (strong, mar- and ultraviolet-resistant polycarbonate) protecting an inner thermoplastic polyester film. The product's technology is based on the film's ability to electrically switch between a high translucent state (providing privacy, glare control, and shading) to a clear state (providing excellent visibility). See **liquid crystal polymer or plastic.**

plastic, liquid A liquid that becomes a solid when converted to its final product use. Depending on its constituents, it can be solidified or cured from room to high temperatures and from vacuum to high pressure.

plastic, long-life The generation of waste is minimized by choosing materials and products that have long lives and optimal recyclability. The design stage needs to consider the effects of later use. Many plastic products have been in service for well over a half century. Most of the plastics in service today were put into production within the past half century. See **aging; energy consumption; incineration; life-cycle analysis; plastics cradle-to-grave; recycling; recycling and lifecycle analysis; vinyl composition tile.**

plastic long-term load behavior See **creep loading.**

plastic, low-profile A thermoset polyester plastic that is used for reinforced plastics and is a combination of thermoset and thermoplastic materials. Although the term *low-profile* and *low-shrink* are sometimes used interchangeably, there is a difference. Low-shrink plastics contain up to 30wt% TP, while low-profile plastics contain from 30 to 50wt% TP. Low-shrink offers minimum surface waviness on molded parts, as low as 25 μm (1 mil) per in mold shrinkage; whereas low-profile offers no surface waviness of 0 to 12.7 μm (0–0.5 in) per in mold shrinkage. See **polyester plastic, thermoset; reinforced plastic; shrinkage; surface finish; tolerance.**

plastic, magnetic Neodymium boron iron that is injection molded with a plastic matrix. Expensive secondary processes are eliminated and more flexible design shapes can be introduced. Ferromagnetism is used in metallic and inorganic materials, but a few are (organic) plastics. See **temperature conductivity, super-.**

plastic manufacture See **fabricating.**

plastic markets, product and material The major U.S. markets for plastics (in wt%) are 25% packaging, 20% building and construction, 12% consumer and institutional, 7% transportation, 6% furniture and furnishings, 5% electrical and electronics, 3% adhesives/inks/coatings, 2% industrial machinery, 10% exports, and 10% other markets. In the United States about 80wt% is thermoplastics and 20wt% is thermoset plastics. See **building and construction; market; packaging; plastic consumption; plastic industry size.**

plastic marriage An undesirable processing situation in which poorly cut pellets become too hot, bond together in strings or clumps, and manage to pass screening. See **plastic types; plastic feed form.**

plastic material Plastic materials for processing are available in different forms and shapes (pellets, flakes, powders, cubes, granular, etc.) with each having certain advantages, such as ease of use in a certain process, ease in compounding, or low cost. They can be delivered in small to large amounts from all kinds of material suppliers worldwide. They can be delivered in 55 lb (25 kg) sacks, gaylords of 1,000 lb (455 kg), semibulk containers (half to a full ton), or in truck or rail car tanks of up to at least 25 tons. See **additive; bulk factor; commodity plastic; compound, premix; computerized database, plastic; concentrate; contamination; design, biotechnology; dicer; die-face pelletizer; engineering plastic; filler; fine; flake; granular material; material blocking; material handling; pellet; pellet, micro-; plastic types; plastic feed form; plastic green strength; plastic, virgin; polymerization, Spheripol process; preform; recycling commingled plastic; reinforcement; storage.**

plastic material drying See **drying operation, hygroscopic plastic; plastic, hygroscopic; venting, feeder.**

plastic material efficiency See **energy efficiency.**

plastic material, heterogeneous A material consisting of dissimilar constituents separately identifiable and consisting of regions of unlike properties separated by internal boundaries. See **equilibrium, heterogeneous; mixture, heterogeneous; nucleation, heterogeneous.**

plastic material, kerf See **cut, kerf, and registration.**

plastic material optimization See **design, material optimization.**

plastic material outgassing During the processing of certain thermoplastic and thermoset plastic compounds, particularly TSs, gas forms and has to be removed so that the gas does not damage the part internally or externally with voids, thin sections, or poor mechanical performance. Release procedures include providing vents and bumping. When applying coatings on plastic, such as metallizing, gas release after coating can cause the coating to be stripped or blistered. See **mold breathing; mold-cavity venting; outgassing; screw venting; venting.**

plastic material process See **fabricating process type.**

plastic material refining The purification and improvement of natural and synthetic products, including petroleum.

plastic material selection To arrive at the optimum material for a given use with some degree of efficiency and reliability, a systematic approach has to identify and list the product requirements, including factors such as aesthetics, tolerances, fabricating process to be used, and surface finish. Publications, seminars, and software can be helpful. In addition to selecting the plastic material, the form that the material is received in—such as pellets, flakes, powder, or liquids—must be selected. Certain processes require certain forms to operate efficiently at the lowest costs. See **CAMPUS database; computer database; computerized database, plastic; computer modeling; computer software; design, material optimization; design, optimized; mixing evaluation; plastics, theoretical versus actual values of; plastic, long-life; plastic material; plastic, virgin; pyrrone plastic; quality and control; recycled-plastic properties; recycling; reinforced plastic; statistical assessment; statistical material selection, reliability of; statistical material selection, uncertainty in; test data and uniform standards; testing and classification; tolerance, molding; training; value analysis.**

plastic material selection, worldwide See **plastic consumption; Table 1, World Consumption of Plastics in the Year 2000 (million lb).**

plastic material, tailor-made See **designing with plastic tailor-made models.**

plastic material to product See **Figure 1, Plastics Simplified Flowchart Guide from Raw Materials to Products.**

plastic material type With 17,000 plastics available worldwide, it is best to recognize that all materials (plastics, metals, etc.) fit into systematic group categories or classifications. Examples of various groupings are thermoplastics, thermosets, reinforced plastics, foams, electrically conductive and nonconductive, weather resistant, high strength, and high stiffness as well as by performance, environments, and products or applications. In spite of the diversity of plastic materials, the basic principle of their construction is always the same. All plastics are macromolecular. Throughout this book a few of the different plastics are reviewed. Many have the prefix "poly" and are not listed here. Others include those listed here. See **acetal plastic; acrolein plastic; acrylamide plastic; acrylate plastic; acrylglass plastic; acrylic plastic; acryloid plastic; acrylonitrile; acrylonitrile-butadiene-styrene plastic; acrylonitrile styrene plastic; alkyd plastic; alloprene plastic; allyl ester plastic; allyl diglycol carbonate plastic; amber plastic; amino plastic; anilene-formaldehyde plastic; carboxymethylcellulose plastic; chloroprene plastic; cyanate plastic; dendrimer plastic; dendritic plastic; diallyl phthalate plastic; diene plastic; epoxy plastic; eraser; etheroxide plastic; ethylene acrylic elastomer; ethylene chlorotrifluoroethylene copolymer plastic; ethylene methyl acrylate copolymer plastic; ethylene n-butyl acrylate copolymer plastic; ethylene plastic; ethylene-propylene plastic; ethylene propylene-diene monomer plastic; ethylene-styrene interpolymer**

plastic; ethylene-vinyl acetate plastic; fluorinated ethylene propylene plastic; fluoroplastic; fluorosilicone plastic; furan plastic; furfural plastic; generic; halocarbon plastic; ionomer; isocyanate; isotactic plastic; ketone; lacquer melamine formaldehyde plastic; methylcellulose plastic; methylfluorosilicone plastic; methylphenylsilicone plastic; methylsilicone plastic; methylvinylfluorosilicone plastic; molecule, macro-; neoprene elastomer; nitrile rubber; nitrile-silicone elastomer; novolak plastic; nylon plastic; olefin-styrene-acrylonitrile; parkesine plastic; parylene plastic; pentadiene plastic; perfluoroalkoxy plastic; perfluorocarbon plastic; perfluoromethylvinyl ether elastomer; phenolic plastic; phenoxy plastic; phenolsilane plastic; plastic, magnetic; polyimide plastic, bismaleimide; polyimide plastic; diadic; propylenoxide rubber/elastomer; propylene plastic; pyrrone plastic; recycling; redox; reinforced plastic material; resole plastic; resorcinol-formaldehyde plastic; rosin; rubber hydrochloride plastic; rubber, natural; rubber, synthetic; safety glass; styrene-acrylonitrile plastic; styrene-butadiene elastomer; styrene-maleic anhydride plastic; styrene-methylmethacrylate plastic; styrene-oligablock elastomer; styrene-paramethylstyrene plastic; styrene-rubber plastic; styrenic plastic; sulfone plastic; thermoflow plastic; zein plastic.

plastic matrix The base plastic that is used during processing, such as the essentially homogeneous thermoplastic or thermoset plastic in which fiber reinforcements are imbedded. See **photochemical hole-burning spectroscopy.**

plastic memory A phenomenon of thermoplastics that has been stretched while hot to return to its original processed or molded form. Different plastics have varying degrees of this characteristic. See **elastic memory; orientation.**

plastic minimization See **design consolidation and minimizing material.**

plastic, modified A plastic that contains ingredients such as fillers, pigments, or other additives that help to vary the physical and other properties of plastics.

plastic money See **legal matter; patent plastic money.**

plastic myth and fact Opponents of plastics object to the fact that plastics are made from petroleum, a nonrenewable resource. A by-product of the distillation of petroleum is ethane, which many years ago was burned as waste. This waste gas has become the building block for most plastics. Reports show that in the United States, from 2 to 3% of all total annual petroleum production is consumed by the plastic industry. Other feedstock materials are used in different parts of the world, but petroleum is the primary feedstock. See **Coca-Cola bottle; Coor's beer bottle; design, experiment; fire and plastic; oil resources, limited; plastic and the future; recycling fact and myth; waste.**

plastic, natural A substance or mixture that occurs in nature; the opposite of synthetic substances, such as practically all plastics. See **amber plastic; balsam plastic; chicle; copal; coumarone-indene plastic; gel, pectin; oleo plastic; plastic, soybean-based; plastic, synthetic; polyhydroxybutyrate plastic; polysaccharide plastic; rubber, natural; sandarac; shellac; synthetic, natural; vulcanized fiber; zein plastic.**

plastic, neat A plastic with Nothing Else Added To it. It is a true virgin polymer since it does not contain additives or fillers. See **biocide; molecular weight and aging.**

plastic, nonpolar A plastic that does not have concentrations of electrical charge on a molecular scale and therefore is incapable of not having significant dielectric loss. Examples are polyethylene and polystyrene plastics. See **dielectric loss.**

plastic, nonrigid A plastic that has a modulus of elasticity of not over 10,000 psi (70 MPa) at 23°C (73°F) and 50% relative humidity. See **plastic, rigid; plastic, semirigid.**

plastic, oil reactive See **oil-reactive plastic.**

plastic, oil soluble See **oil-paint, reactive plastic.**

plastic, oligomer A plastic consisting of only a few monomer units—for example, a dimer, trimer, or their mixtures.

plastic, organic See **chemistry, inorganic; chemistry, organic.**

plastic, organometallic A plastic that contains metals either in the backbone chains or pendent to them. The metals may be connected to the plastic by bonds to carbon. See **chemical configuration.**

plastic paper To date most plastic papers are biaxial oriented and film-based. Pulp can be made in a polymerization reactor by vigorous stirring HDPE and other plastics, which forms fibers. Some combinations have been made with wood pulp. Fibrous spun-bonded plastics such as DuPont's Tyvek can be considered a plastic paper. Nonfibrous plastic films are paperized by internal or external methods. Internal involves cavitation during orientation, generally with fine particle fillers as the sites of cavitation using combinations such as HDPE/calcium carbonate and PP/clay/titanium dioxide. Other methods are used, such as employing incompatible plastics. External paperized products include certain coated films and those combining fillers and coatings. The packaging film that best fits the definition of a synthetic paper is opaque BOPP (bioriented PP) film. Higher cost to date has restricted the expansion in the use of plastic paper. However, growth has been occurring as a replacement for conventional high quality paper where it is scarce such as in the Middle East, Asia, and possibly North Africa. See **fabric, nonwoven spun-bonded; fiber processing, spinning; legal matter: patent plastic money; orientation; paper; Tyvek.**

plastic performance, mechanical Mechanical behavior determines the strength and endurance of a plastic under stress. Modulus, strain, strength, and toughness are typically measured. These parameters are useful for raw-material inspection as well as process and product evaluation. See **creep; mechanical market; modulus; strain; stress; testing; toughness.**

plastic, porous Plastic with different degrees of openings that can range from 5 to 20,000 micron, and that are created by mechanical, chemical, or spark methods. It is used for controlled venting, aeration, filtration, and muffling in different environments (chemical corrosion, abrasion, sound, etc.). See **aerogel.**

plastic, preceramic The extremely high softening temperature of ceramics precludes their being shaped into films, fibers, or other complex shapes through the melt processing that is common to plastics. The use of preceramic plastics (ceramic precursors), which are processed as ordinary plastics to the desired shape and then pyrolyzed to ceramics, can overcome the high-temperature shaping situation. Most ceramics derived from preceramic plastics are silicone-based.

plastic processing The best processing melts for any plastics start with the plastic manufacturer's recommended heat profile or one's own experience. Various types of plastics have different starting points that have to be interfaced with the equipment to be used. The time and effort on startup make it possible to achieve maximum efficiency of performance versus cost for the processed plastics. By the application of logic with available control systems, the information gained can be stored and applied to future setups. See **fabricating process; fabricating processing repeatability; fabricating processing type; fabricating startup and shutdown.**

To understand potential problems and their solutions, it is helpful to consider the relationships of machine capabilities, plastics processing variables, and product performances. A distinction has to be made between machine conditions and processing variables. For example, machine conditions include operating temperature and pressure, mold or die temperature, and machine output rate. Processing variables are more specific, such as the melt condition in the mold or die and the flow rate versus temperature. See **FALLO approach; morphology; polymer, reactive; profit and technology.**

plastic product failure Practically all incidences of malfunctions are caused by a lack of knowledge of the characteristics and potentials of the plastics, with a resultant misapplication, rather than from any shortcomings in the material itself. In other words, the correct design, correct material, and proper fabrication can meet cost-property efficiency. Unfortunately, lower-cost materials and processing techniques sometimes are assumed to be equal to the more expensive parts that do not fail. Industry standards and specifications are always being developed to make the public aware of inferior parts but usually are issued after the problem or failure develops. See **crazing; design-failure theory; design-failure theory, Griffith; design safety factor; failure fault tree analysis; plastic failure or success; plastic, long-life; plastic material and equipment variable; problems and solutions; quality-system regulation.**

plastic products, raw material to Raw materials are the precursor of a processed (virgin) plastic that combines with additives, fillers, or reinforcements to become a plastic. The following steps are involved: (1) the raw material or energy source (petroleum, natural gas, coal, agriculture, etc.) produces (2) feedstock (ethane, propane, benzene, etc.), which produces (3) monomer (ethylene, propylene, styrene, etc.), which produces (4) polymer, which produces (5) plastic (additive, filler, reinforcement), which is fabricated according to a (6) process (extrusion, injection molding, blow molding, etc.), to produce (7) marketable products (packaging, building and construction, electronics, etc.). See **coal; feedstock; oil and gas; oil, cracking; petrochemicals; plastic consumption; plastic material; plastic processing; plastic, virgin; polymerization; supply chain; Figure 1, Plastics Simplified Flow Chart Guide from Raw Materials to Products.**

plastic properties Molecular weight, molecular weight distribution, structure, composition, and other molecular parameters govern the physical, mechanical, and chemical properties of plastics. Also involved are the nonplastic additives, such as stabilizers, antioxidants, plasticizers, flame retardants, colors, calcium carbonate, wood fibers, and milled glass. These additives and fillers are used in the plastic compounds to enhance certain processing or product performance characteristics as well as reduce costs. For example, graphite powder filler can change shrinkage performances, such as significantly reducing or expanding plastics. The properties of plastics directly depend on temperature, pressure, time, and environmental or service conditions. In turn, these properties can be related to raw material, processing, and product performance. Testing is done on the finished product as well as on the plastic materials prior to and during processing. See **chemical and physical characteristics; designing with plastic tailor-made models; market; optically active plastic; plastics, theoretical versus actual values of; shrinkage.**

plastic property and understanding polymer structure See **Staudinger, Hermann.**

plastic, pseu- See **viscosity, non-Newtonian flow.**

plastic, reactive See **polymer, reactive.**

plastic received See **material received, checking.**

plastic, reclaim PET See **coating, oxygen-barrier removable.**

plastic, reformulated Recycled plastic that has been upgraded to alter or improve performance capability or to change characteristics through use of additives. See **recyclable.**

plastic, renewable See **resource, renewable.**

plastic, reprocessed A thermoplastic that is prepared from melt-processed scrap, rejected parts, or nonstandard or nonuniform virgin plastic. The term *scrap* does not necessarily connote feedstock that is less than desirable than the material from which it may have been generated. The reprocessed plastic may be reformulated with additives. See **plastic, reformulated; recycling.**

plastic-rich A localized area that is filled with plastic and lacks reinforcements or fillers. See **reinforced plastic, resin-rich; starved area.**

plastic, rigid A general classification where a plastic has a modulus of elasticity either in tension or flexure greater than 100 ksi (690 MPa) at 70°F (21°C) and 50% relative humidity. See **modulus; plastic, nonrigid; plastic semirigid.**

plastics and electronic toys Microprocessor-based toys use technology in innovative ways. MIT's Media Laboratory's Toys of Tomorrow (TOT) is a consortium that was organized in April 1998 to explain the toy technology. Members include Acer, Bandai America, Deutsche Telekom, Energizer, Intel, Disney, LEGO, Mattel, Motorola, Polar Electro Oy, TOMY, and the International Olympic Committee. Toys will be the first devices to deliver a networking technology infrastructure to the home and may be precursors of technologies that eventually end up in the workplace. See **computers; toy.**

plastics cradle-to-grave In cradle-to-grave analyses, plastic far outperforms the other materials. The studies compared the materials based on energy consumption, air emissions, waterborne wastes, and solid-waste products. Life-cycle assessment is a comprehensive means of comparing the impact that different materials, product designs, fabrication processes, and waste-disposal methods have on the environment. This technique sets plastics in a favorable light versus competitive materials. See **ISO-14000 certification; life-cycle analysis; plastic, long-life; profit and time; time.**

plastic, crystalline See **amorphous plastic; crystalline plastic; semicrystalline plastic.**

plastic scrap See **cut, kerf, and registration.**

plastic segregation The separation thermoplastic molded surface part as in wavy lines or color striations. With thermoset plastic, usually a separation of plastic and filler occurs on the surface.

plastic, self-reinforcing A plastic with densely packed, fibrous polymer chains, such as a liquid crystal polymer. See **liquid crystal polymer or plastic.**

plastic, semirigid A plastic that has a modulus of elasticity in tension or flexure between 10 to 100 ksi (70 to 690 MPa) at 70°F (21°C) and 50% relative humidity. See **modulus; plastic, nonrigid; plastic, rigid.**

Plastics Institute of America (PIA) An educational and research group that was established in 1961 and dedicated to education and research in the plastics industry. See **education; training; Appendix C, Worldwide Plastics Industry Associations.**

plastic, semicrystalline See **amorphous plastic; crystalline plastic; semicrystalline plastic.**

plastic, smart The ability of smart plastics to respond to a stimulus such as stress, heat, light, or electricity enables them to be used as the intelligent components of sophisticated systems. An early example was using birefringence to monitor stresses in plastic components. Designs have emerged from the integration of sensing, information processing, and actuating functionalities within plastics. Continuous reinforcement in reinforced plastics offers special opportunities for online evaluation of both stress exposure and life expectancy. See **birefringence; device, smart; reinforced plastic; sensor; stress.**

plastic softening range The range of temperatures within which a plastic changes from a rigid to a soft state. Actual values depend on the test method and material used. Sometimes it is incorrectly referred to as the *softening point*. See **test.**

plastic solidification During melt processing of amorphous and crystalline plastics, changes in plastic volume and temperature differ. With crystalline plastic the volume change increases very fast at its melt temperature (T_m), but with amorphous plastic it is gradual. Thus, during processing these two types of plastics require different heating profiles. See **amorphous plastic; crystalline plastic; melt flow; solidification point.**

plastic solvation The process of swelling, gelling, or dissolving a plastic by a solvent or plasticizer. In this process an ion or polar molecule is held strongly to solvent molecules in a solution. See **ion; molecule, polar; solution.**

plastic sorting See **recycling, automatic-sorting.**

plastic, soybean-based A University of Delaware program has produced an all-natural, high-performance plastic that includes the use of renewable soybean oil.

Plastics Pioneer Association (PPA) An association that was established in 1942 to recognize members of the plastics community with a long record of service. See **Appendix C, Worldwide Plastics Industry Associations.**

plastics, theoretical versus actual values of In 1944, based on the laws of physics, chemistry, and mechanics, theoretical property values were determined for various materials. Since that time steel, aluminum, and glass theoretical and actual values have remained practically the same, but values for plastics have greatly improved (as was predicted in 1944). Since that date, plastic properties (strength, modulus, etc.) have significantly increased from 10 to 50% but have not reached the theoretical potential that was predicted during 1944. See **datum; design theory and strength of material; fiber processing, spinning; fiber, spider-silk; plastic material selection; plastic properties; reinforced plastic; reinforcement.**

Comparison of 1944 Theoretical to Actual Properties

	Modulus of Elasticity			Tensile Strength		
		Experimental			Experimental	
Type of Material	Theoretical N/mm^2 (kpsi)	Fiber, N/mm^2 (kpsi)	Normal Polymer N/mm^2 (kpsi)	Theoretical, N/mm^2 (kpsi)	Fiber, N/mm^2 (kpsi)	Normal Polymer, N/mm^2 (kpsi)
Polyethylene	300,000	100,000	1,000	27,000	1,500	30
		(33%)	(0.33%)		(5.5%)	(0.1%)
	(43,500)	(14,500)	(145)	(3,900)	(218)	(4.4)
Polypropylene	50,000	20,000	1,600	16,000	1,300	38
		(40%)	(3.2%)		(8.1%)	(0.24%)
	(7,250)	(2,900)	(232)	(2,300)	(189)	(5.5)
Polyamide 66	160,000	5,000	2,000	27,000	1,700	50
		(3%)	(1.3%)		(6.3%)	(0.18%)
	(23,200)	(725)	(290)	(3,900)	(246)	(7.2)
Glass	80,000	80,000	70,000	11,000	4,000	55
		(100%)	(87.5%)		(36%)	(0.5%)
	(11,600)	(11,600)	(10,100)	(1,600)	(580)	(8.0)
Steel	210,000	210,000	210,000	21,000	4,000	1,400
		(100%)	(100%)		(19%)	(6.67%)
	(30,400)	(30,400)	(30,400)	(3,050)	(580)	(203)
Aluminum	76,000	76,000	76,000	7,600	800	600
		(100%)	(100%)		(10.5%)	(7.89%)
	(11,000)	(11,000)	(11,000)	(1,100)	(116)	(87)

* For the experimental values the percentage of the theoretically calculated values is given in parentheses.

plastic, stir-in See **vinyl plastic, stir-in.**

plastic, strengthened See **design theory and strength of material; strengthening plastic mechanism.**

plastic structural form See **amorphous plastic; crystalline plastic; semicrystalline plastic.**

plastic structure See **molecular-arrangement structure.**

plastic, super- A plastic (polymer) of very high molecular weight. See **engineering plastic; plastics, theoretical versus actual values; reinforced plastic.**

plastic, syntactic cellular See **reinforced plastic syntactic cellular plastic.**

plastic, synthetic A plastic that is produced from the polymerization of its monomer or monomers by a chemical reaction controlled by people, as opposed to a natural plastic that is produced by biosynthesis. Natural plastics that have been chemically modified to produce different materials are also called synthetic plastics. See **plastic; synthetic, natural; vulcanizate.**

plastic system A mixture or compound of plastics and other ingredients, such as catalysts, initiators, dilutents, additives, fillers, and reinforcements, that is required to produce products meeting specific properties.

plastic, tailor-made See **designing with plastic tailor-made models.**

plastic-to-metal bond See **metal adsorption calorimetry; metal-to-plastic bond.**

plastic transfer molding See **reinforced-plastic resin transfer molding.**

plastic types Plastics are usually obtained in the form of granules, powders, flakes, and pellets and sometimes in liquid form. They are classified as thermoplastic (TP) or thermoset (TS). TPs represent 90wt% of all plastics consumed. TPs become soft and extrudable on heating without undergoing significant chemical or performance changes. On cooling they harden. This cycle can be repeated. TS plastics are rigid and undergo cross-linking or chemical change during processing and after curing cannot normally be resoftened or reprocessed. There are TP and TS elastomers (rubberlike).

Of the 17,000 plastics available worldwide, about 200 basic types are commercially recognized, and fewer than 20 are popularly used. About two-thirds of all plastics consumed are LDPE, HDPE, PP, PVC, and PS. The relatively new generation of high-performance metallocene and elastomeric plastics are in this group. The basic types, with their many different additives, fillers, grafts, and alloys provide different processing capabilities and product performances. See **catalyst, metallocene; commodity plastic; engineering plastic; plastic; plastic feed form; plastic, long-life; plastic marriage; plastic material; plastic products, raw material to; reliability; thermoplastic; thermoset plastic.**

plastic, unstable See **metastable.**

plastic, virgin A plastic material in the form of pellets, granules, powder, flock, or liquid that has not been subjected to use or processing other than what was required for its initial manufacture. See **plastic material; recycled-plastic properties; recycling.**

plastic void content See **reinforced plastic void content; void.**

plastic waste See **design packaging; recycle; waste; waste, plastic.**

plastic, water condensation See **storage and condensation.**

plastic, water-soluble Any plastic of high molecular weight that swells or dissolves in water at normal room temperature. The principal members of this class are certain polyvinyl alcohols, ethylene oxides, polyvinyl pyrrolidones, and polyethyleneimides. Also called *water soluble adhesive*. See **acrylate plastic; carboxymethylcellulose; methylcellulose plastic; polyvinyl pyrroldone plastic; solubility.**

plastic wood See **wood-plastic composite process; wood-plastic impregnated.**

plastic worker See **fabricating employment.**

plastic, XT Cyro Industries' tradename for its family of impact acrylics that permit a wide range of transparent or opaque colors.

plastify See **plasticate.**

plastigel A plastisol that exhibits gellike flow or puttylike consistency properties. It is a plastic to which a thickening agent has been applied. See **gel; thickening agent.**

plastisol A mixture of vinyl plastic and plasticizers that is heated and can be processed by different methods, such as casting, coating, dipping, rotational molding, and spreading, to produce flexible to hard parts. It is a liquid suspension of a finely divided plastic (about 1 μm) in a plasticizer. With heat, the plasticizer is absorbed into the particles and solvates them so that they fuse together to produce a homogeneous plastic mass. See **coating, coil; coating, dip; forming, dip; fusion; gel; gelation; organosol; plastic dispersion; plasticizer; plastigel; polyvinyl chloride dispersion plastic; rigidsol; solvating action; vinyl; viscosity, depressant.**

plastisol blending extender plastic A blending plastic that is used with vinyl plastisols and organosols and that has larger particle size and lower cost than the dispersion plastics normally used. It can be used as a partial replacement for the primary plastic. In addition to cost reduction, it sometimes changes properties. See **blending; extender.**

plastisol, fused A plastisol that has been heated to the temperature at which it becomes a single homogeneous phase; related to cure.

plastisol hardened See **rigidsol.**

plastisol, modified A plastisol that contains additional ingredients such as blowing agents to produce foamed plastic. See **foam and blowing agent; plastic dispersion; polyvinyl chloride dispersion plastic plastisol.**

plastometer See **rheometer; test, plastometer meltflow.**

platelet See **reinforcement, disk.**

platen The plates on which a mold is fastened. In compression-molding machines, it is some times referred to as the *deck*. See **clamping platen; die platen.**

platen, floating A platen that is situated between the main two platens in a multidaylight press, such as in injection-molding and compression-molding machines. There can be more than one floating platen. Total clamping pressure is applied on each platen.

platen, multidaylight A machine that has two or more movable platens.

platen press The basic compression press has two platens. The basic injection-molding machine used to have three platens—two to operate the closing and opening of a mold and one to provide support to a pressure clamping system applied to the mold. Since the 1960s, two-platen IMMs have become more popular to operate the mold. Technical devices usually located in the back of a platen or tiebars operate the pressure-clamping system. The two-platen press may provide improved technical performances and cost advantages such as reduced weight, reduced floor space, significantly reduced clamp speed, resulting in shortened cycle time, and reduced tonnage when compared to a hydraulic press. See **clamping, hydraulic; press.**

plate-out An objectionable coating that gradually forms on the metal surfaces of molds, dies, calendering rolls, and embossing rolls. It is caused by the extraction and deposition of certain components in the plastic, such as pigments, lubricants, plasticizers, stabilizers. See **defect.**

plating See **coating, sputtered; coating vacuum; electroless plating; electrophoretic deposition; electroplating; metallizing plastic; metallizing, vacuum; polish; surface finish; surface treatment.**

plating, silver-spray A chemical spray metallizing process that is based on the glass mirror art. The plastic part is prepared by cleaning and lacquering as in vacuum metallizing and then the lacquer coat is sensitized in an acidic salt bath. A silver-forming solution (silver nitrate and an aldehyde) is sprayed on the part, usually with a two-nozzle spray gun so that the components are separated until they reach the surface. A final topcoat of protective lacquer is applied over the silver. See **iridescence; metallizing, vacuum.**

plexifilament See **fabric, nonwoven flash-spun.**

plug forming See **hermoforming, plug.**

plunger 1. The male portion of a mold. See **mold cavity, male. 2.** In compression molding, a device (also called *core*) that pushes or forces material into the opening of the female mold. See **compression molding. 3.** The part of an injection- or transfer-molding machine that applies pressure to the material being processed. With the usual screw-injection machine, when pressure is applied to the melted shot, the screw usually stops rotating and acts as a plunger. See **extruder ram; injection molding machine ram; transfer molding.**

ply **1.** In general, a layer in a fabric or felt (laminates, reinforced plastic, coextruded film, etc.). See **fabric. 2.** In filament winding, a single pass where two plies form one layer. See **filament winding. 3.** A yarn that results from twisting operations. See **yarn.**

plywood A form of bonded laminated wood in which successful layers of wood veneers (thin wood) are usually cross-laminated. Its core can be a veneer, saw lumber in one piece, or lumber in several pieces under heat and pressure, using usually phenolic and urea plastics. See **adhesive, plywood; laminate wood; veneer.**

pneumatic Air-powered, operated, or controlled system in which energy is transferred by compression flow and expansion of air. See **conservation of matter, law of; hydraulic.**

pneumatic control See **thermoforming, pneumatic control.**

pneumatic loader/conveyer See **material handling, pneumatic loader and conveyer.**

pocket, plastic An accumulation of excess plastic in a small, localized section that is visible on cut edges of products or internal to the product and not visible. Also called *resin pocket.* See **defect.**

pock mark See **blow molding, extruder, pock mark.**

poise (P) The metric system unit of viscosity, expressed as 1 dyne per second per square centimeter. A cP is 0.01 of a poise. See **viscosity; viscosity, stoke.**

Poiseuille's equation See **flow, Poiseuille.**

poison See **toxicity.**

Poisson's ratio See **design, Poisson's ratio in.**

polar See **molecule, polar.**

polarimeter An instrument that is used to determine the amount of rotation of the direction of vibration of polarized light by the test specimen. It determines the amount of polarization of light by the specimen or in the illuminating beam.

polariscope An optical (polarizing) microscope in which the incident light passes through a pair of polarizing filters (analyzers). The polarizer polarizes the beam that illuminates the test specimen, and the analyzer analyzes the effect, if any, on the polarized light. With a birefringent specimen (crystalline thermoplastic) light passes through and forms an image. This technique is used to observe the orientation of spherulites and crystallites. See **birefringence; crystallite; photoelasticity.**

polarity The sign of the charge on a molecule or side chain. When plastics contain other atoms in addition to carbon and hydrogen, they are generally more negative than carbon and hydrogen. The resulting polarity produces electrical attractions between the molecules. These attractions pull and hold molecules close together. They are often measured by solubility in different solvents, quantified as the "solubility" parameter. These polar attractions improve many end-use properties. They generally require more heat to overcome them and permit melt processing, as melting points and processing temperatures are generally higher than for less polar plastics. When the chemist uses too much polar attraction action, the plastic will not melt or flow until it reaches the decomposition temperature. See **chemical synthesis; solubility parameter.**

polarizability The extent to which a dipole moment can be introduced.

polarized light Light waves that are selectively oriented by passing through a filter. Under polarized light, amorphous areas appear black, while crystalline areas are clear and have multicolored patterns. This occurs because crystalline plastics have molecules that crystallize and fold together in a uniformly orderly manner, whereas amorphous plastics do not produce crystallites and their molecules are in a random pattern. See **amorphous plastic; birefringence; chemical analysis; crystal; crystalline plastic; haze; polarimeter; polariscope; stress, residual; test, microtoming optical-analysis; test, nondestructive photoelastic stress-analysis; transparent plastic.**

polarizing lens A lens that is used to qualitively evaluate birefringence in clear, transparent products.

polarizing light plane Light in which the electric field and magnetic field components are confined to specific planes.

polarizing microscope See **polariscope.**

polar winding See **filament winding, polar.**

polish A solid powder, liquid, or semiliquid mixture that imparts smoothness, surface protection, or decorative finish. See **ash, bone; buffing; carnauba wax; coconut shell; finishing, ashing and lapping; plating; surface finish; water beading.**

polishing agent See **ash, bone; pigment, rouge.**

polishing, cold-gas Because the appeal of exterior surfaces is so important, major efforts are made at assembly plants handling plastic parts to fix surface imperfections caused by dust, dirt, and dings. Conventional buffing and polishing do not always work because friction-induced heat can damage irreversibly the highly flexible plastic paints and plastics. The cold-gas technique (originally from Germany) uses liquid nitrogen and combines nitrogen gas with a 3M Co. polishing compound called Finesse-It to eliminate frictional damage. Nitrogen gas flows through a flexible, heat-insulated hose to a polishing tool driven by compressed air. The gas emerges at the center of the polishing pad at temperatures between $-40°$ to $-76°$F ($-40°$ to $-60°$C).

polishing, solvent A method of improving the gloss of thermoplastic parts by immersion or spraying with a solvent, dissolving surface irregularities, followed by evaporation of the solvent. See **surface finish.**

pollution Substances in any environment (atmosphere, land, water, etc.) that are not normally present therein and that are potentially toxic or otherwise objectionable. The most serious atmospheric contaminants have been sulfur dioxide (burning fuel in plants) and automobile exhaust gases rich in carbon dioxide. Certain plastics can introduce pollutants if not properly handled using devices such as scrubbers. See **energy consumption;**

plastic and pollution; polychlorofluorocarbon; recyclable; recycling energy consumption; scrubber; toxicity.

pollution, air Air pollutants can be classified by their physical and chemical characteristics. The more common type include dust, entrained liquids, entrained particles, fumes, mists, and noxious gases. The removal of these contaminants usually requires special equipment or scrubbers, such as carbon absorbers, catalytic equipment, cyclones, electrostatic precipitators, fine-fabric filters, gas absorbers, ion-exchange columns, venturis, and scrubbers (wet, dry, venturi). See **atmosphere, dry deposition; contamination; dust; powder coating; scrubber; venturi.**

pollution and marine standard See **bottle standard reference material.**

pollution control See **biodegrading microorganisms.**

pollution, thermal The release of heat into rivers and lakes, thus raising the temperature to levels that are harmful to various forms of life.

pollution, water Water-quality objectives call for effective design and operation of wastewater treatment facilities, using the continually better available, practical, or demonstrated technologies. Accurate measurement of pollutants is the critical factor in operating or maintaining the systems that include filtration and aeration capabilities. See **acid rain; adsorption; pollution.**

polomeric See **polyester reinforced urethane plastic.**

poly- A prefix denoting "many." Thus, the term *polymer* means "many mers." See **polymer mer.**

polyacetal plastic See **acetal plastic.**

polyacrylamide plastic (PAM) A strongly polar, water-soluble plastic. When cross-linked, it forms a network structure. When lightly cross-linked PAM can be swollen with water to form rubberlike gels that are widely used to separate small molecules. See **chromatography, gel; gel; plastic, water-soluble.**

polyacrylate plastic See **acrylate plastic.**

polyacrylonitrile plastic (PAN) A base material or precursor in the manufacture of carbon fibers. See **chromatography, gel; fiber, carbon; pitch.**

polyalkoxythiophene plastic See **moisture, humectant agent.**

polyallomer plastic A crystalline thermoplastic block copolymer that is made of ethylene, propylene, and sometimes other unsaturated monomers. It is produced by anionic coordination polymerization. It has high-impact strength, low density, long flexural life, and excellent stress cracking resistance. See **ethylene-propylene copolymer plastic; polymerization.**

polyamide-imide plastic (PAI) An engineering thermoplastic that is characterized by excellent dimensional stability, high strength and modulus, and good impact at continuous high temperatures of 260°C (450°F). In the uncured form it is soluble in polar organic solvents. The imide linkage is formed by heating and producing an infusible plastic with thermal stability up to 290°C (550°F). See **imide; polyimide plastic.**

polyamide plastic (PA) Also called *nylon.* See **nylon plastic.**

polyaniline plastic See **welding, microwave.**

polariscope See **photoelasticity.**

polyarylamide plastic See **fiber, aramid; fiber, nylon; Kevlar.**

polyarylate plastic A thermoplastic that is tough, durable, and heat resistant and has excellent ultraviolet stability and electrical properties, flame resistance, and wear resistance. It's major use is in outdoor lighting.

polyarylene ether phosphine oxide plastic (PAEPO) A plastic that, in different thermoplastic forms, such as films and as matrix or coating materials for reinforced plastics, is highly compatible both physically and chemically with liquid oxygen (LOX). Some PAEPOs are a clear, colorless material called *colorless oxygen resistant* (COR). The films have passed the Marshall Space Flight Center LOX mechanical-impact-sensitivity test at the maximum required energy level of 72 ft-lb (98 J). They are soluble in a number of polar solvents and can therefore be applied from solution onto complexly shaped surfaces with relative ease, such as with dip coating or brushing. These films can be very thin if necessary, and they adhere well to composites made of other component materials. See **adhesive; pipe; tank.**

These PAEPOs can be used as matrix materials in reinforced plastics, along with graphite fiber, using different reinforced-plastic fabricating processes that range from bag to autoclave molding. Tanks and pipes using this RP construction are used to handle and contain LOX for NASA. They are compatible with other component materials, such as toughened epoxies and graphite fibers and other constructions. However, poor adhesion or the need to process them at temperatures high enough to damage other component materials can inhibit their use. With epoxy-graphite RP structure, the film (solventless) becomes intimately bonded with the underlying RP by use of the RP cocure process. This method has a thin film applied on the side of the RP prepreg layup prior to curing. During the cure, the film forms a strong bond with the epoxy matrix. See **fiber; reinforced plastic.**

polyaryletherketone plastic (PAEK) A high-performance thermoplastic. For example, in reinforced plastics they may have a continuous-use temperature as high as 250°C (480°F).

polyaryl sulfone plastic (PAS) An easy-to-process thermoplastic. A very important characteristic is resistance to low and high temperatures from −240 to +260°C (−400 to +500°F). It also has resistance to chemicals, oils, and most solvents and has good impact resistance and electrical insulating properties.

polybenzimidazole plastic (PBI) A dark-brown thermoplastic with a high degree of thermal and chemical stability. It is used in fibers for resistance to very high temperatures and flame, aerospace applications, protective coatings, and reinforced plastics. See **triallyl cyanurate.**

polybutylene terephthalate plastic (PBT) A saturated thermoplastic polyester that is prepared by transesterification of dimethyl terephthalate with butanediol during melt polycondensation. It has heat resistance, good tensile strength, dimensional stability, low moisture absorption, dielectric properties, and chemical resistance, except for resistance to strong bases and halogenated solvents. Water absorption is very low. The plastic has a relatively low impact strength and thermal stability, but these can be easily overcome by proper modification.

polycaprolactam plastic A cyclic amide-type compound containing six carbon atoms. It is polymerized into nylon 6. Also known as *caprolactam plastic.* See **chemical reclamation; nylon plastic.**

polycarbonate plastic (PC) A thermoplastic that is prepared by either phosgenation of dihydric phenols such as bisphenol A or by ester exchange between diaryl phenol. It has the highest impact resistance of any transparent plastic, good mechanical properties, especially impact strength, high heat-deflection temperature, and low moisture absorption and exhibits clarity and good thermal and oxidative stability. They are self-extinguishing, and some grades are transparent. See **aromatic polyester ester carbonate plastic.**

polycarbonate polyurethane plastic, medical An implantable plastic that was developed for medical use after polyether-based plastics could not be used. This material was developed and patented by Cardio Tech International Inc. of Woburn, MA. See **medical application.**

polychlorinated tetrafluoroethylene plastic An aqueous dispersion that provides extremely low flammability with an oxygen index of 93%, high light transmission of over 90%, and excellent barrier properties. It has higher moisture barrier than PTFE or PVDF and processes at lower temperatures of 90° to 200°C (194° to 392°F) versus 400°C (723°F). Processing includes injection and compression molding, extrusion, and coating.

polychlorofluorocarbon (PCFC) Any of a family of inert, nontoxic, nonflammable, and easily produced liquified chemicals, principally used in refrigeration, air conditioning, packaging, cleaning solvent, aerosol propellant, and certain plastic foams. Based on the Montreal protocol and Kyoto protocol, worldwide concerns about the possibility of depleting the ozone layer in the upper atmosphere have forced industry to find alternatives to PCFCs. As a cleaner, it has been used in medical devices and electronic devices to clean and degrease stainless steel, titanium, silicone, PE, PTFE, gold-ribbon conductors that are to be spot welded, and polybags that used to hold parts. An alternative to CFC is the hydrochlorofluorocarbon and a single-fluid vapor degreasing process using 3M's HFE-7100. The hydrofluoroether (HFE) is listed in the U.S. Environmental Protection Agency's New Alternatives Policy as acceptable without restrictions for use as an alternative to ozone-depleting substances. Also called *chlorofluorocarbon* or *CFC.* See **carbon dioxide; chemical, fluoro-; environmentally friendly additive; fluoroplastic; foam and blowing agent; hazard; hydrochlorofluorocarbon; ozone; pentane gas; Petite; protocol, Kyoto; protocol, Montreal.**

polychloroprene rubber/elastomer (CR) Neoprene was one of the first synthetic rubbers that had desirable properties in many applications, such as open-side drive belts. This family of elastomers includes some rubbers with high dynamic load-bearing capacity and good heat resistance. Also called *neoprene.* See **neoprene rubber/elastomer.**

polychlorosulfonated polyethylene plastic See **polyethylene plastic, polychlorosulfonated.**

polychlorotrifluoroethylene plastic (PCTFE) A tough, rigid thermoplastic of excellent thermal stability, outstanding electrical properties, and chemical inertness.

polycondensate A product of condensation polymerization. See **condensation agent.**

polycondensation See **polymerization, condensation.**

polyelectrolyte A substance that, on dissolving in water or other ionizing solvents, dissociates to give polyions (multiple charged ions) together with an equivalent amount of ions of small charge and opposite sign.

polyester plastic A large class of plastics usually made by condensation of polyol with polycarboxylic acid or anhydride, or polycondensation of hydroxycarboxylic acid. Some thermoset polyester consist of alkyd plastics and unsaturated plastics. The thermoplastic polyesters include elastomers. The processing techniques, properties, and applications of polyesters vary widely. See **design, biotechnology; copolyester elastomer; plastic, low-profile.**

polyester plastic, aromatic (ARP) A thermoplastic that is tough, durable, and heat resistant and offers good dimensional stability, dielectric properties, ultraviolet stability, and flame retardance. Chemical resistance is somewhat lower than other engineering plastics. Also called *polyarylate.* See **aromatic polyester ester carbonate plastic.**

polyester plastic, isophthalate A thermoset unsaturated polyester that is based on phthalic anhydride. Also called *isophthalic polyester.*

polyester plastic, liquid-crystal A thermoset that is comprised of highly aromatic copolyesters with a highly ordered structure in both melt and solid states. They have very high tensile and flexural strengths at elevated temperatures and are resistant to all chemicals, weathering, radiation, and burning. They are processed by sintering and injection molding. See **liquid crystal polymer or plastic.**

polyester plastic, thermoplastic Two important thermoplastics are polyethylene terephthalate (PET) and polybutylene terephthalate (PBT). The major use for the PETs is as film, fibers, and soda bottles. The PBTs are primarily used in molding compounds. See **window.**

polyester plastic, thermoset An important use of thermoset polyester plastic is as a liquid that is cross-linked with styrene and used as the matrix plastics in fabricating reinforced plastics. Types of molding compounds include sheet-molding compounds, bulk molding compounds, and thick-molding compounds. In liquid or solid forms different types of molding compounds are prepared, such as alkyd and diallyl phthalate plastics. The curing does not result in any byproduct, such as water (as with condensation plastics). See **alkyd plastic; allyl diglycol carbonate plastic; catalyst, benzoyl peroxide; diallyl phthalate plastic; maleic anhydride; plastic, low-profile; sewer rehabilitation; sheet-molding compound.**

polyester plastic, unsaturated A thermoset plastic that is commonly used in fabricating reinforced plastics and is characterized by vinyl unsaturation in the polyester backbone. This compound enables subsequent hardening or curing by copolymerization with a reactive monomer in which the polyester constituent has been dissolved. See **phthalic anhydride.**

polyester plastic, water-extended A thermoset casting plastic formulation in which water is suspended in the polyester plastic.

polyester reinforced urethane plastic A poromeric, microporous material with urethane impregnation or silicone coating for shoe uppers and industrial leathers. See **porous, micro-.**

polyether chlorinated plastic A family of thermoplastics with outstanding chemical resistance and possessing excellent heat resistance and electrical properties.

polyether-imide plastic (PEI) A thermoplastic that has good thermal properties with continuous-use temperature of about 170°C (338°F). The T_g is about 215°C (419°F). See **imide.**

polyether sulfone plastic A high-temperature thermoplastic with good transparency and flame resistance. It is one of the lowest smoke-emitting plastics available.

polyethylene naphthalate plastic (PEN) A high-barrier, heat-resistant thermoplastic polyester that is used in products such as bioriented stretched bottles and thermoformed packages.

polyethylene oxide plastic See **plastic, water-soluble.**

polyethylene plastic (PE) One of the olefin family with many different formulations. U.S. consumption is HDPE 42wt%, LLDPE 27%, LDPE 20%, EVA 4%, others (VLDPE, MDPE, UHMWPE, etc.) 7%. It is one of the most versatile of plastics. In common usage these translucent, waxlike plastics have no less than 85% ethylene and no less than 95% total olefins. These thermoplastics can be cross-linked by irradiation or chemically resulting in thermosets with improved strength and dielectric properties. They are normally translucent, tough, waxy solids that are unaffected by a large range of chemicals. The usual TPs have good impact resistance at low temperatures, chemical resistance, and moisture resistance with high thermal expansion. Food grades are available. Also called *polythene.* See **fiber processing, gel-spinning; polybutylene terephthalate plastic; polyethylene terephthalate plastic; surface treatment; telcothene plastic; terephthalate.**

polyethylene plastic, chlorinated (CPE) The moderate random chlorination of polyethylene suppresses crystallinity and yields CPE, a rubberlike material, going from soft to hard, that can be cross-linked with organic peroxides. The chlorine content of this elastomer is in the range of 36 to 42% compared to about 56.8% in PVC. CPE has good to excellent heat, oil, oxygen, ozone, weather, chemical extraction, and tear strength resistance. It is used as a plasticizer for PVC.

polyethylene plastic, chlorosulfonated See **geomembrane.**

polyethylene plastic, cross-linked See **extruder wire and cable cross-linking PE with peroxide; extruder wire and cable cross-linking PE without peroxide.**

polyethylene plastic fiber See **fiber processing, gel-spinning; fiber processing, solution-spinning.**

polyethylene plastic, high-density (HDPE) A linear polyethylene with density of 0.94 to 0.97 g/cm^3, molecular weight of 50,000 to 250,000, and high crystallinity. It is produced by co- or homopolymerization in a slurry or gas phase at relatively low pressure and temperature. It has excellent low-temperature toughness, chemical resistance, good dielectric properties, and relatively high softening temperatures. The properties improve with decreasing polydispersity. See **extruder, solid-state.**

polyethylene plastic, linear (LPE) A polyolefin with linear carbon chains. LPEs are prepared by copolymerization of ethylene with small amounts of higher alfa-olefins such as 1-butene. They are stiff, tough, and have good resistance to environmental cracking and low temperatures.

polyethylene plastic, linear low-density (LLDPE) A linear carbon-chain copolymer of ethylene with higher alfa-olefins such as 1 butene and 1 hexane, having density of 0.91 to 0.94 g/cm^3. LLDPEs are prepared by solution or gas-phase copolymerization. Compared to LDPE, they have better tensile, tear, and impact strength and crack resistance properties.

polyethylene plastic, low density (LDPE) A branched carbon-chain polyethylene thermoplastic that is prepared by homopolymerization of ethylene under high pressure. Its density is 0.91 to 0.94 g/cm^3; there is also very low-density polyethylene (VLDPE). It has high toughness, impact strength, flexibility, film transparency, chemical resistance, good dielectric properties, and low water permeability and brittleness temperature. It is cross-linkable, producing a thermoset plastic. See **ethylene-ethyl acrylate plastic.**

polyethylene plastic, polychlorosulfonated (PCSPE) A thermoset elastomer that provides excellent weather resistance even in light colors; excellent resistance to abrasion, crack growth, oil (similar to neoprene), ozone, heat, weather, flame, oxidizing chemicals, and solvents; good dielectric properties;

low gas permeability for an elastomer; low moisture absorption; low temperature flexibility at −40°C (−40°F); and good adhesion to substrates. It is used in hoses, tubings, roll covers, footwear, and building products. Also called *chlorosulfonated PE rubber, CSPE,* or *CSM.*

polyethylene plastic, terephthalate See **polyethylene terephthalate plastic.**

polyethylene plastic, terephthalate, glycol-modified (PETG) With the addition of glycol, PETG prevents plastic crystallization and provides a broader process window than PET. PETG parts have good clarity, toughness, and ESCR performance, as well as good gas-barrier properties.

polyethylene plastic, ultrahigh-molecular-weight (UHMWPE) A linear carbon-chain polyethylene that is specially prepared by a process such as the Ziegler polymerization of ethylene. UHMWPEs have very high wear resistance, chemical resistance, and low coefficient of friction and are self-lubricating; however, they do not melt in the conventional way. In powder form, they are processed by sintering, compression molding, and ram extrusion, resulting in molecular weights of 4 to 6 million. See **detonation; extruder, ram; fiber processing, gel-spinning; injection molding ultrahigh-molecular-weight polyethylene.**

polyethylene plastic, vulcanizable A grade of polyethylene that lends itself to cross-linking producing plastics that are thermoset plastics, thereby acquiring improved properties, such as increased strength and heat distortion.

polyethylene terephthalate plastic (PET) A saturated thermoplastic polyester that is prepared by polycondensation of ethylene glycol with terephthalic acid or its dimethyl ester. PETs are extremely hard, wear resistant, dimensionally stable, and resistant to chemicals and have excellent gas barrier properties (used in stretched-injection blow-molded carbonated beverage bottles) and good dielectric properties and clarity. Its tensile strength and thermal stability improve dramatically with increasing crystallinity and orientation. See **bottle, cryogenically cooled filling; coating, oxygen-barrier removable; reinforced plastic, XTC.**

polyethylene-vinyl alcohol plastic (EVOH) A thermoplastic that has excellent gas and vapor barrier properties and high mechanical strength, gloss, elasticity, weatherability, and resistance to solvents and oils. Clarity, surface hardness, and abrasion resistance are high. They absorb moisture, which affects their performance as vapor barriers. Other plastics are used to barrier cover them and eliminate the moisture problem. Their processability improves and the absorption of moisture decreases with increasing content of ethylene. They are used extensively in packaging. Also called *ethylene-vinyl alcohol plastic* or *EVAL.*

polyhydroxybutyrate plastic (PHB) A natural plant-grown plastic. Genetics have been used to create a plant that makes this PHB plastic. See **biodegradable.**

polyimide plastic There are thermoplastic and thermoset plastic types. Thermoplastics (TPIs) have superior tensile and compressive strengths at temperatures up to 315°C (600°F) with good dimensional stability, creep, impact, and chemical resistance. There are polyamide-imides with high thermal stability, low flammability, and good adhesive, dielectric, and barrier properties. However, they have rather poor processability due to the highly viscoelastic behavior of the melt. Processing is by compression and injection molding and various powder sintering, film casting, and solution coating techniques. The thermosets (TSIs) require curing at elevated temperatures. Their properties are similar to the TP types; however, they have good processability due to their low melt viscosity. TPs have exceptionally good thermomechanical performance characteristics. See **imide; polyamide-imide plastic; polyimide plastic, bismaleimide.**

polyimide plastic, bismaleimide (BMI) A type of polyimide that cures by an addition rather than a condensation reaction, thus avoiding problems with volatiles formation. It is prepared by a vinyl-type polymerization of a prepolymer terminated with two maleimide groups. It is intermediate in temperature capability between epoxy and polyimide.

polyimide plastic, diadic A polyimide plastic that is produced by the condensation of a diamine and a dicarboxylic acid.

polyimide plastic, polymerization of monomer reactants (PMR) A class of high temperature-resistant plastics.

polyion A multiple-charged ion.

polyisobutylene butyl rubber (PIB) A remarkably different rubber. It has very low gas permeability and very high damping properties. See **damping; rubber.**

polyisoprene rubber/plastic The basis for natural rubber (thermoset), gutta-percha, and other rubberlike materials. It is also made synthetically by producing thermoplastic elastomers. See **latex, natural rubber.**

polyketone plastic (PK) A class of thermoplastics, such as polyetherketones and polyetheretherketones. See **Carilon.**

polylactic plastic (PLA) A biodegradable thermoplastic polyester made from polylactic acid that is produced by bacterial fermentation of cornstarch or sugar beets. PLA can be fully compostable and is recyclable. They have strength, stiffness, chemical and impact resistance, good wear and friction characteristics, wide temperature range, and wide processing window. This elastic plastic is used to produce tough, water-resistant coatings. See **biodegradable.**

polyliner **1.** A plastic bag that is placed inside a container to prevent its contents from being contaminated. **2.** A perforated, longitudinally ribbed sleeve that fits inside the cylinder of a ram (not screw) of an injection-molding machine.

polymer A substance consisting of large molecules formed by the joining together of simple molecules that are known as *monomers.* The term comes from the Greek *poly* ("many") and *meros* ("parts"). Where two or more monomers are involved, the resultant product is known as a *copolymer.* For example, polymerization of ethylene forms a polyethylene plastic or condensation of phenol and formaldehyde (with production of water) forms phenol-formaldehyde plastics. See **chemical composition and properties of plastic; chemical polymer; molecular structure; plastic; plastic, neat.**

polymer, addition A plastic that is formed by the addition of unsaturated monomer molecules, such as olefins, with one another, without the formation of a by-product such as water. Examples are polyethylene, polypropylene, and polystyrene plastics. Also called *addition plastic.* See **plastic material type.**

polymer, block A polymer whose molecule is made up of alternating sections of one chemical composition separated by sections of a different chemical structure or by a coupling group of low molecular weight. For example, blocks of PVC may be interspersed with blocks of PVAC. See **copolymer, block.**

polymer, branched A polymer that is composed of molecules having a branch structure, chainlike between branch junctions and between each chain end and a branch junction. See **temperature sensitivity.**

polymer chain stiffening A polymer strengthening mechanism that is significantly different from linear, branched, or cross-linked. It has a monomer that is physically large and unsymmetrical. The ability of a chain to flex is impaired. A typical example is polystyrene plastic.

polymer chain transfer (CT) The termination of a growing polymer chain and the start of a new one. The process is mediated by a change-transfer agent, which may be a monomer, initiator, solvent, or some species added deliberately to effect the chain transfer. Because CT occurs in all radical polymerization, it must be taken into account in any quantitative considerations of these reactions. CT always decreases the molecular weight. See **molecular weight.**

polymer chain-transfer agent A molecule from which an atom, such as hydrogen, may be readily attracted by a free radical.

polymer characterization Polymers are categorized as natural or synthetic and as homopolymers or copolymers. Copolymers and terpolymers are further classified according to the method of production and the arrangement of the monomeric units. Other methods are used. The techniques may not be uniformly applicable to all classes of polymers.

polymer charge-transfer See **polymerization charge-transfer.**

polymer, chemical See **chemical polymer; design, biotechnology.**

polymer chemical reagent Polymer-supported catalysts are a particularly attractive type of polymer-support reactant because a relatively small amount is used to chemically transform a relatively large amount of substrate. After the reaction, the polymer-supported species can be separated without difficulty from low-molecular-weight species in solution. Separation is most readily achieved if the polymer is cross-linked since it is then insoluble in all solvents.

polymer chemistry terminology Stated simply, polymers can be made up of carbon (C), hydrogen (H), chlorine (Cl), fluorine (F), oxygen (O), and nitrogen (N). These six elements, either naturally or synthetically, first form simple molecules called *monomers.* When these monomers are subjected to a catalyst, heat, and pressure, the double bonds (or connecting arms of the monomers) open up, and these individual monomer units join arms to form long chains called *polymers.* This process is called *polymerization.* Different chemical structures are formed for the different polymers. The geometry (linear, branched, and cross-linked) of their chains is as important as their chemical makeup in determining properties. See **amorphous plastic; catalyst; chemical composition and properties of plastic; chemistry; cross-linking; crystalline plastic; definition, art of; molecular bonding; molecular structure; molecule; monomer; polymerization.**

polymer combination See **interpenetrating network.**

polymer cross-linked density The fraction of a polymer chain unit, normally the repeat units, that is cross-linked. If there is N such units (since each cross-link links two such units), the fraction number of cross-links will be $N/2$.

polymer disproportionation A chain transfer between macroradicals to produce a saturated and unsaturated polymer molecule.

polymer evolution In the pioneering age of polymeric evolution, new plastics were determined primarily via the selection of suitable monomer components. Today the number of new polymers or plastics that are developed primarily on the basis of known monomers is on the increase. This also applies to new plastic blends and compounds based on known plastics. A similar situation exists with catalysts. See **catalyst.**

polymer, full-contour length The length of a fully extended polymer chain.

polymer, graft A polymer that is comprised of molecules in which the main backbone chain of atoms has attached to it at various points side chains containing different atoms or groups from those in the main chain. The main chain may be a copolymer or may be derived from a single monomer. See **copolymer, graft; material, microphase structure.**

polymer, head-to-head A polymer chain configuration in which the functional groups are on adjacent carbon atoms.

polymer, head-to-tail A polymer chain configuration in which the functional groups on adjacent polymers are as far apart as possible.

polymer, high A macromolecular substance that, as indicated by the term *polymer,* consists of molecules that are at least approximately multiples of the low molecular units. Molecular weight is greater than 10,000, usually composed of repeating units of low-molecular-weight species such as ethylene and propylene.

polymer, high derived A polymer that has been produced by chemical alteration of a primary high polymer or a natural high polymer.

polymer, homo- A plastic or polymer that is formed from a single monomer species.

polymer, inter- A particular type of copolymer in which two monomer units are so intimately distributed in the polymer molecule that the substance is essentially homogeneous in chemical composition. Also called *true polymer.*

polymer, isomeric A polymer that has essentially the same percentage composition as another but differs with regard to molecular structure. See **monomer, isotactic.**

polymer, isomerism Having the same molecular and chemical composition but different chemical properties and structure due to different positions of atoms or molecules.

polymerization **1.** The bonding of two or more monomers to produce polymers or plastics. A chemical reaction, addition, or condensation in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of that of the original substance resulting in high-molecular-weight components. See **alkali metals and derivatives; boron compound; dilatometer; morphology and mechanical property; plasticizer, internal; plastic products, raw material to; polymer chain transfer; polymerization, co-; reactor technology. 2.** Any chemical reaction that produces bonding. See **alkali metals and derivatives; chemical reaction; reactor technology.**

polymerization, addition A chemical reaction (polymerization) in which simple molecules (monomers) are added to each other to form long-chain molecules (polymers) and no byproducts are formed (water, gases, etc.).

polymerization, aldehyde A process that proceeds by bond-opening, chain-reaction polymerization of carbonyl group of an aldehyde, and results in the formation of polyaldehyde plastic (also called *acetal plastics*).

polymerization, anionic Vinyl polymerization that proceeds by the addition of certain monomers to activate center-bearing whole or partial negative charges. See **polymer living system.**

polymerization, aqueous Vinyl polymerization with water as the medium and with the monomer present within its inherent solubility limit. It includes suspension polymerization in an aqueous medium. This procedure is of technical importance in preparing special plastics such as emulsifier-free latex in which the size distribution among the dispersed particles is fairly sharp. See **coating, waterborne system.**

polymerization, block A term that has been applied to both bulk polymerization (casting of polymerizing syrup) and sequence copolymerization (block copolymerization). Only the latter is recognized by IUPAC as true copolymerization. Confusion may be avoided to some extent by the use of the prefix *co*, which implies the polymerization of more than one monomer.

polymerization building block See **Staudinger, Hermann.**

polymerization, bulk The simplest and oldest method for the synthesis of macromolecules. It begins with undiluted low-molecular-weight starting materials. This method has a reaction, which is relatively simple and rapid, plastics of high purity are formed, and the plastics obtained are immediately processable. The polymerization process involves only monomer and polymerization initiator or catalyst. It is carried out in the absence of a solvent or other dispersion media. This technique is applicable to both addition and condensation polymerization. Also called *mass polymerization* or *step-growth polymerization.* See **polymerization, solution.**

polymerization, catalytic The polymerization of monomers to form high-molecular-weight molecules in the presence of catalysts.

polymerization catalyst A catalyst that assists polymerization. See **catalyst.**

polymerization catalyst, metallocene See **catalyst, metallocene.**

polymerization, cationic Polymerization in which the active end of the growing molecule is a positive ion. The ion may be the carbonium ion, in which case the process is frequently referred to as a *carbonium ion polymerization*, or the ixonium ion.

polymerization, chain The two basic types are stepwise (or step reaction) and chain reaction. Their kinetics are entirely different; their properties differ based on molecular-weight distribution. The chain types are generally known as *addition polymerization.* See **polymerization, addition.**

polymerization charge-transfer Charge-transfer polymerization is initiated by means of charge-transfer interactions involving monomers as one or both components of an electron donor-acceptor system. The term's charge-transfer initiation and charge-transfer propagation distinguish polymerizations that involve charge-transfer phenomena in the initiation process from those that involve charge-transfer complexes in the propagation process. Thermally and photochemically induced charge-transfer polymerization involves novel types of initiation.

polymerization chemistry See **alkali metals and derivatives.**

polymerization, co- The polymerization of a mixture of two or more monomers yields a copolymer with two different repeating units distributed along the polymer chain. Copolymerization has practical utility for altering the properties of a homopolymer (produced from a single monomer) in a desired reaction. Copolymer properties are determined by the identities of the two monomers and their relative amounts in the copolymer. Also called *heter-*

polymerization. See **copolymer, block; copolymer, graft; polymerization.**

polymerization, condensation A chemical reaction in which two or more molecules combine, accompanied by the separation of water or some other simple substance. Also called *polycondensation.* See **chemical reaction, condensation.**

polymerization, condensation cloud point The temperature at which the first turbidity appears, caused by water separation when the reaction mixture is initiated.

polymerization, cross-linked See **interpenetrating network.**

polymerization, de- Breaking down into component parts of a polymerization reaction or reversing the reaction. Such reversals occur in certain plastics when exposed to very high temperatures. See **recycling, chemical.**

polymerization, degree of The number of structural units, or mers, in the average polymer molecule in a sample measure of molecular weight. Alternately, the average number of mers (monomer units) per molecule if the molecules have been (or could hypothetically be) produced from identical monomers. See **viscosity, K-value.**

polymerization, electron-beam (EB) A slow irradiating process. Monomeric materials that have been irradiated to produce plastic films include silicone, butadiene, styrene, methyl methacrylate, and epoxy. However the lack of selectivity of this energy source can result in contamination. Film properties can be tailored by varying the acceleration voltage. See **coating, vacuum.**

polymerization, emulsion Polymerization of monomers dispersed in an aqueous emulsion. Polymerization is in a stabilized emulsion, at least at the start of the reaction. See **emulsion; film formation; micelle.**

polymerization, free-radical A type of polymerization where the propagating species is a long-chain free radical initiated by the introduction of free radicals from the thermal or photochemical decomposition of an initiator molecule.

polymerization, gas-phase A process for polymerization of polyolefins that was introduced in the late 1960s. It entails a gaseous monomer and catalyst going into a continuous reactor, followed by removal of dry, free-flowing plastic powder ready to be pelletized and sold.

polymerization heat See **exotherm heat.**

polymerization history The polymerization of ethylene under high pressure (about 2,000 bar) was discovered in 1933 by the English chemists Fawcett and Gibson. The German scientist Ziegler discovered the alternative low-pressure process (near atmospheric pressure). See **plastic history; Ziegler process.**

polymerization homopolymer A polymer that results from polymerization of a single monomer.

polymerization inhibitor A substance that, mixed with the monomer, retards the initiation of polymerization.

polymerization initiator In emulsion polymerization of a monomer, a material that is necessary to start the reaction. An example is the making of nylon thread from a beaker containing a lower layer of a solution of sebacyl chloride in carbon tetrachloride and upper layer of hexamethylene diamine in aqueous solution. A pair of tweezers is gently lowered through the top layer, closed on the interfacial layer of plastic, then drawn upward to pull with it a continuous strand of nylon.

polymerization, interfacial A reaction that occurs at the interfacial boundary of two solutions.

polymerization, ion-beam Ion beams can be used in a manner similar to electron beams to polymerize gaseous organic monomers. Also called *ionic polymerization.* See **coating, vacuum.**

polymerization, ionic A process in which the monomer or a mixture of monomers is added to agents containing electrically charged ions, usually conducted in solution with a liquid diluent. Typical plastics produced include cumarone-idene, polyisobutylene, butyl rubber, and polyvinyl ether. Also called *cationic polymerization* or *anionic polymerization.*

polymerization, ionization A type of polymerization in which the active agent is an electrically charged atom or group of atoms called *ions.* See **ionization.**

polymerization, living plastic system The term *living polymer* is often used to describe systems in which active centers remain after complete polymerization, so that a new batch of monomer subsequently added to the existing chains increases their degree of polymerization.

polymerization, mass See **polymerization, bulk.**

polymerization, photo- Photopolymerization is the polymerization initiated by the interaction of light, usually ultraviolet wavelengths, with a photosensitive compound, producing free radicals. The compound may be a monomer itself (styrene, etc.) that absorbs a photon to give an excited state, which itself then disassociates to free radicals. Since the 1940s, reinforced plastics have been fabricated with thermoset polyester plastics compounded with photosensitive agents. See **radiation-induced reaction; radiation, photon; reinforced plastic.**

polymerization reaction See **exotherm.**

polymerization regulator In a polymerization system, a substance that modifies the shapes and sizes of the molecules. It may hinder the formation of branches and cross-links, for example, and so delay the formation of gels. Also called *modifier.* See **modifier.**

polymerization, short stopper An agent to a polymerization reaction mixture to inhibit or terminate polymerization.

polymerization, solution Similar to bulk polymerization except that the solvent in solution action is usually a chemically inert medium, whereas the solvent for forming the polymer in bulk is the monomer. The solvents used may be complete, partial, or nonsolvents for growing polymer chains. When the monomer and polymer are both soluble in the solvent, initiation and propagation of the growing polymer chains take place in the monomer phase. Because of the mass-action law, rates of polymerization in solvents are slower than in bulk and the molecular weight of the polymers formed is decreased. When the monomer is soluble in the solvent but the polymer is only partially soluble or completely insoluble in the solvent, initiation of the polymerization takes place in the solvent phase. However, as the polymer molecules grow, some of the propagation of polymers take place within the monomer-swollen molecules that are beginning to precipitate from the reaction. When this happens, it can become possible to build up MW because of the decreased dilution within the polymers. Thus, MWs as high as those possible with bulk can also be achieved. See **polymerization, bulk; reactor technology; solution.**

polymerization, Spheripol process A patented Himont Inc. process that produces PP plastic in beads, crumbs, or granular forms, eliminating any pelletizing finishing operation.

polymerization, step-reaction A mechanism in which the general reaction involves two molecules or molecular fragments of arbitrary size. Their classes include condensation polymerization and rearrangement by skeletal bond interchange.

polymerization, stereochemistry See **chemistry, stereo-.**

polymerization, stereo specific See **Ziegler process.**

polymerization, suspension A technique that is normally used only for catalyst-initiated or free-radical addition polymerizations. The monomer and dissolved catalyst is mechanically dispersed in a liquid, usually water, that is a nonsolvent for the monomer as well as for polymer molecules that form during the reaction. The advantage of this system over bulk polymerization is that it allows the operator to effectively cool the exothermic polymerization reactions and thus maintain closer control over the chain-building process. Also called *pearl polymerization.* See **reactor technology.**

polymerization, thermal A thermal petroleum-refining process that is used to convert light hydrocarbon gases into liquid fuels. Paraffinic hydrocarbons are cracked to produce olefinic material, which is concurrently polymerized by heat and pressure to form liquids. The product is known as plastic gasoline.

polymerization, vapor deposition See **xylylene plastic.**

polymerization, Ziegler-Natta See **Ziegler-Natta polymerization.**

polymer, ladder A polymer that has two polymer chains cross-linked at intervals. See **molecule alignment.**

polymer living system A system in which active centers remain after complete polymerization, so that a new batch of monomer subsequently is added to the existing chains and increases their degree of polymerization. See **monomer.**

polymer matrix See **plastic matrix.**

polymer mer A repeating structural unit of any high polymer or plastic. See **copolymer; monomer plastic; poly-; polymerization, degree of.**

polymer molecule See **molecule, macro.**

polymer molecule building block See **Staudinger, Hermann.**

polymer network A three-dimensional reticulate structure formed by chemical or physical linking of the polymer chains. See **rubber elasticity.**

polymer, pre- A chemical intermediate with a molecular weight between that of the monomer or monomers and the final polymer or plastic. A reactive prepolymer is a low- to medium-molecular-weight prepolymer that provides versatility, ease of handling, low shrinkage, and gap filling ability. It is solvent free (100% solids) and chemically reactive. On cure it produces a chemically cross-linked thermoset plastic. When used as an adhesive, a one-component system is generally heat or atmospheric moisture or oxygen cured, while two-component systems react with one another at ambient temperature or elevated temperature.

polymer, primary high One produced directly from small molecules, without chemical alteration subsequent to the polymerization.

polymer, reactive A device that alloys different materials by changing their molecular structure inside a machine. True reactive alloying induces an interaction between different phases of an incompatible mixture and ensures the stability of the mixture's morphology. There are a variety of reactive alloying techniques available, and they typically require a reactive agent and compatibilizer to bring about a molecular change in one or more of the blend components, thereby facilitating bonding. This concept produces thousands of new elastomeric to rigid compounds to meet specific product design requirements. See **alloy/blend; compatibilizer agent; fabricating process.**

polymer, reactive elastomer Materials with very good elastomeric properties are produced in single-step reactive polymer systems from low-molecular reactive chemicals. For the thermoplastic elastomers, the mechanism is similar to thermoset elastomers, but relatively infrequent cross-linking is required; chain polymerization is favored. Examples are certain types of polyurethane and silicone elastomers. The starting chemicals are normally in liquid form and easy to process into products. The reaction can be triggered by heat, catalyst, or mixing, as in the case of TS elastomers.

polymer, reactive-processing Traditionally, manufacturing products made from plastics involved two distinct operations—reaction and processing. Polymerization reactions make monomer molecules into polymer/plastic molecules, and fabricating processing equipment transforms the plastic molecules into shapes. Reactive processing combines these two operations by conducting polymerization and polymer/plastic modification reactions in a processing machine such as reactive extruder processing and reaction-injection molding. See **extruder, reactive-processing; polymerization; reaction-injection molding.**

polymer reactivity The end group of a polymer is frequently the most reactive point in the entire molecule. The lower mobility of high-molecular-weight polymers makes them much less reactive to normal chemical reactions than similar functional groups would be in conventional low-molecular-weight monomeric structures. To this extent, increasing MW would be expected to decrease reactivity quite rapidly and then taper off at the higher MWs. See **molecular weight.**

polymer, renewable A material that is produced in the animal and plant kingdoms. Polymers from renewable resources refer to natural products that are polymeric as grown or can be polymerized.

polymer stereochemistry See **chemistry, stereo-.**

polymer structure See **molecular-structure configuration.**

polymer synthesis See **alkali metals and derivatives.**

polymer, tailor-made See **designing with plastic tailor-made models.**

polymer, ter- A polymer that is formed from three monomer species or units such as ABS.

polymethylmethacrylate plastic See **acrylic plastic; casting, acrylic-sheet.**

polymethylpentane plastic (PMP) A thermoplastic polyolefin with very low density (0.83 g/cm^3); high light transmission and melting point; and good rigidity, dielectric, tensile properties, and chemical resistance. It is used in laboratory ware, extrusion coated paper, high-intensity light fixtures, auto parts such as radiator plugs, sight glasses, wire insulation, and small appliances.

polymorphism The ability of an element or compound capable of a stable existence in different temperature and pressure ranges to exist in two or more crystalline phases. See **temperature properties of plastic.**

polyol **1.** A chemical compound with more than one reactive hydroxyl group. With foamed plastics, the term includes compounds containing alcohol hydroxyl groups such as polyethers, glycols, polyesters, and castor oil used in polyurethane foams, and other polyurethanes. **2.** Also called *polyhydric alcohol* or *polyalcohol.* See **foam; foamed polyurethane, reaction-injection molding.**

polyolefin plastic A very large class of carbon-chain thermoplastics and elastomers. The most important are polyethylenes and polypropylenes. They all are extensively used in many different forms and applications. Also called *olefin, olefinic plastics,* or *olefinic resins.* See **polyethylene plastic.**

polyolefin plastic, bonding See **chromic acid etching.**

polyolefin plastomer plastic (POP) A plastic that is made using single-site catalysts and features narrow-molecular-weight distribution and uniform incorporation of octene, butene, or hexene comonomer. POPs offer the highest to date oxygen transmission rate, lowest heat-seal initiation temperature, very high seal strength, low moisture transmission rate, excellent optics, and toughness. However, they are tacky, and have low modulus and rather high cost. See **barrier plastic; catalyst; molecular-weight distribution; packaging, modified-atmosphere.**

polyolefin, thermoplastic (TPO) A PP modified with at least 20wt% olefinic rubber (EPDM,EPR, or metallocene-catalyzed ethylene copolymer). It is used in bumper guards, wheel well liners, and step pads. They offer a combination of low cost, low density, wide modulus range, high flexural strength, low temperature impact, and recyclability. See **automobile bumper fascia.**

polyol OH-number The number of mg of KOH that is chemically equivalent to the activity of a specified weight (g) of the polyol.

polyoxymethane plastic (POM) See **acetal plastic.**

polyphenyleneether plastic A thermoplastic polyphenylene ether alloy with polystyrene, usually high impact PS. They have high-impact strength and improved resistance to heat, fire, and chemicals compared to polystyrene. See **ether-oxide plastic.**

polyphenylene oxide plastic (PPO) A thermoplastic that has a useful temperature range of −170 to +190°C (−275 to +375°F) with intermittent use up to 205°C (400°F). Other properties include excellent electrical and good resistance to acids and bases. Also called *polyphenylene ether plastic* (PPE).

polyphenylene sulfide plastic (PPS) A thermoplastic with excellent chemical resistance, thermal stability, and fire resistance. It is used in electrical/electronic and automotive parts.

polyphosphazene plastic An isophobic coating plastic/elastomer that offers more anti-icing effectiveness and durability than fluorocarbon and silicone elastomers. They can reduce the accumulation of ice on aircraft, ships, antennas, ground radomes, and power transmission lines. They reduce the adhesive forces between ice and a surface of any material because they combine low surface tension with a low modulus of elasticity (having a rubbery character), low glass transmission temperature, good environmental stability, curability, and moderate cost. The monomer or additive mixtures can cure by heating or by use of such chemical initiators as Michier's ketone in the presence of ultraviolet light. In addition, an interpenetrating network plastic can be made from a blend of the phosphazene elastomer with isocyanate prepolymers. These compounds then cure on exposure to moisture, trapping and bonding the phosphazene to the coated surface. Physical properties can be varied over a wide range by use of either core-action or IPN-type cures and of silane coupling bonding agents. See **aircraft;**

icephobic coating; interpenetrating network; surface tension.

polypropylene-butene plastic A family of PP random copolymers that uses butene as the comonomer and that was commercialized in 1993 by Shell Chemical Co. under the trademark Cefor. It was the first time butene, a C4 hydrocarbon that contains four carbon atoms, had been used. (Typically, suppliers offer PP copolymerized with ethylene, a C2 monomer, or terpolymerized with combinations of propylene, ethylene, and butene.) Butene provides an optimization to balance properties found in cast and biaxially oriented PP films. It offers improved stiffness, clarity, and heat-seal initiation temperature as compared to traditional random copolymer PPs. The latter property is a key determinant of OPP line speeds. Butene has inherently better compatibility with PP and superior long-term retention of low-haze properties compared to ethylene. See **atom carbon, asymmetric.**

polypropylene, multiple monomer An unusual palette of alloyed PP copolymers and homopolymers made by the Himont Inc. Catalloy process. Catalloy is an in-reactor alloying process, not a plastic or product name. It is a way of introducing elastomers into the PP matrix and combining homopolymers to achieve different properties. Also called *reactor granule technology*.

polypropylene plastic (PP) A thermoplastic that has low density, good flexibility, and resistance to chemicals, abrasion, moisture, and stress cracking. It has excellent processing and performance-to-cost advantages. See **polymerization, Spheripol process; stereospecific; plastic.** Because of its good organoleptic properties, PP is ideal for food applications as well as other markets such as pharmaceutical and medical. See **blow molding; bottle; medical-device packaging clarity; organoleptic.**

polypropylene plastic, crystallization control. See **blow molding, stretched.**

polysaccharide plastic Naturally occurring polymers that consist of simple sugars. Examples are starch and cellulose. See **cellulose, natural.**

polystyrene plastic (PS) A popular crystalline class of thermoplastic that is produced by homopolymerization of styrene. It has good rigidity, high dimensional stability, low moisture absorption, optical clarity, high gloss, stain resistance, and outstanding electric properties. Because it is somewhat brittle, it is often copolymerized or blended with other plastics to obtain many different property improvements.

polystyrene plastic, crystal This styrenic material is an amorphous homopolymer that offers improved stiffness, dimensional stability, good optical properties, and electrical insulation capabilities. It is different than the standard impact-resistant PS plastics.

polystyrene plastic, expandable See **expandable polystyrene.**

polystyrene plastic, general purpose (GPPS) An amorphous plastic that is prepared by homopolymerization of styrene. It has excellent clarity, gloss, good tensile and flexural strengths, high light transmission, and adequate resistance to water, detergents, and inorganic chemicals. Also called *crystal polystyrene*.

polystyrene plastic, impact A thermoplastic that is produced by modifying PS with rubber, such as butadiene rubber or with butadiene copolymers. It has excellent impact strength, good dimensional stability, high rigidity, and good low temperature impact/strength. Also called *styrene rubber plastic* or *high-impact PS*. See **rubber, synthetic; syndiotactic.**

polystyrene plastic, syndiotactic (SPS) An engineered, crystalline styrene plastic created by metallocene catalyst technology and offering chemical resistance and a 270°C (518°F) melting point for heat resistance comparable to that of PPS, LCP, and thermoplastic polyester. Its T_g is 100°C (212°F). It also has good impact resistance, tensile and flexural strength, and low moisture absorption. See **syndiotactic.**

polysulfide plastic A large class of thermoplastics containing repeating linkages in the aromatic, alicyclic, or aliphatic backbone. The most important families are polythiophenylenes and sulfide rubber. The former resemble polyethers with sulfur substituting for oxygen; the latter has usually a series of connected sulfur atoms in the repeating unit. The material is elastomeric in its natural form, resistant to light, oil, and solvents, and impermeable to gases.

polysulfone plastic (PSU) A class of thermoplastics that are characterized by the presence of sulfone linkages in their repeating units. Most are aromatic and also contain ether linkages to enhance oxidation resistance. As a class PSUs have high strengths and very high service temperature and show excellent thermal stability, low creep, good dielectric properties, transparency, self-extinguishing, and resistance to chemicals. The most important and popular are the polyarylsulfone and polyethersulfone.

polytetrafluoroethylene plastic (PTFE) A fluorocarbon that is best known for its extreme inertness to chemicals, low friction, nonsticking, easy release properties, extreme resistance to many environments (acids, alkali, etc.), good electrical and thermal insulator, low flammability, high weatherability, and high impact strength. It is extensively used to coat and protect materials (steel, etc.). The permeability of these fluorocarbons are also high, whereas strength and creep resistance are relatively low. In the human body, it is very inert when in its bulk form. Its very high melt viscosity tends to restrict processing to sinter moldings and powder coatings. It is used in coatings for cooking utensils, chemical apparatus, electrical and nonstick items, bearings, and containers. As spheres it is used as fillers, and in oil form it is used as lubricants in various plastics. Also called *TFE*. See **extruder wire and cable, ram; extruder paste; film, skived; tetrafluoroethylene.**

polythene plastic See **polyethylene plastic.**

polytrimethylene terephthalate plastic (PTT) Shell's PTT combines the chemical resistance of PET with the elastic recovery of nylon. It also has inherent stain resistance, easy printability and dyeability, good colorfastness against ultraviolet light, low static generation, low water absorption, and a melting point of 230°C (446°F).

polyurethane plastic (PUR) A large class of thermoplastics (TPUs) and thermosets (TSUs) with the backbone consisting of repeating units containing urethane groups. PURs are usually prepared by interfacial polycondensation of polyisocyanates with polyols. The latter may be based on polyesters, polyethers, or both. Basic constituents include toluene diisocyanate (TDI) and diphenylmethane diisocyanate (MDI). Important types are the urethane rubbers, nonelastomeric TP, urethane TP elastomers, and TS urethane plastics. They may be rigid to soft and flexible or cellular or solid and offer a wide range of properties depending on composition and molecular structure. They can be tailored within very wide limits to meet different desired applications. In general, they have high abrasion resistance, good retention of properties at low temperatures with ease of formability, outstanding toughness in both warm and cold environments, chemical resistance, flex fatigue resistance, vibration dampening, and a "soft touch" feel. Their major markets are in construction, transportation, carpet cushion, furniture, appliances, coatings, and adhesives. Also called PU or *urethane plastic.* See **additive chain extender; fiber, spandex; foam; interpenetrating network; isocyanate; polyester reinforced urethane plastic; polyol; reaction-injection molding.**

polyurethane plastic, medical See **polycarbonate polyurethane plastic, medical.**

polyurethane plastic, nonelastomeric thermoplastic Polyisocyanate polyol plastics that are not chemically cross-linked. They have high abrasion resistance, good retention of properties at low temperatures, but poor heat resistance, weatherability, and resistance to solvents. PURs are flammable and are made with a toxic substance (isocyanates) that is safe to handle and use. Also called *TPU, rigid TP polyurethane, polyurethane,* or *RTPU.*

polyurethane plastic, nonelastomeric thermoset Polyisocyanate polyol prepolymers or monomer mixtures that can be cured at moderate or ambient temperatures in the presence of catalysts. Cured plastics have a wide range of good properties that include high abrasion resistance, good retention of properties at low temperatures, but poor heat resistance, weatherability, and resistance to solvents. They are flammable and are made from toxic substances (isocyanates) that are safe to handle. Also called *urethane plastic/resin, urethane, PUR, PU,* or *rigid RTSU.*

polyvinyl acetal plastic Part of the thermoplastic vinyl family that has three main groups—polyvinyl acetate (PVAC), polyvinyl alcohol (PVAL), and polyvinyl butyral (PVB).

polyvinyl acetate plastic (PVAC) A colorless, odorless, light-stable thermoplastic that is unaffected by water, gasoline, or oils. It is soluble in lower alcohols, benzene, and chlorinated hydrocarbons. PVAC can be cast, coated, extruded, or molded, but its main uses are in adhesives, lacquers, and films. See **adhesive, polyvinyl acetate.**

polyvinyl alcohol plastic (PVAL) Normally a granular, colorless, solid that is insoluble in most organic solvents and oils. They are soluble in water when the content of hydroxy groups in the plastic are sufficiently high. It is used mainly in adhesives and coatings. See **plastic, water-soluble.**

polyvinyl butyral plastic (PVB) A colorless, flexible, tough solid. It is used as a coating, adhesive, and interlayer in safety glass. See **safety glass.**

polyvinyl butyral plastic, transparent-to-translucent change See **glass, switchable.**

polyvinyl carbazole plastic A thermoplastic that has excellent electrical properties and good heat and chemical resistance. It is used as an impregnant for paper capacitors. See **carbazole.**

polyvinyl chloride acetate plastic A copolymer that is a colorless solid with good resistance to water as well as concentrated acids and alkalies. Compounded with plasticizers it yields flexible materials that are superior to natural rubbers in aging properties.

polyvinyl chloride dispersion plastic A special variety of PVC. About 10wt% are used by dispersing directly into plasticizers and then fusing to provide dip and other coatings and molding. See **coating, dip; organosol; plastisol; plastisol, modified.**

polyvinyl chloride plastic (PVC) A white powder plastic that can be formulated to be flexible to rigid. It is extensively used to fabricate many different products using many different fabricating processes. PVC is a thermoplastic prepared by free-radical polymerization of vinyl chloride in dispersion (emulsion), bulk, or suspension processes. A small amount of comonomer is sometimes added to enhance adhesion or other properties. Unmodified PVCs are rigid and requires plasticizers to make them flexible. The manufacture of a wide range of plastics is possible because of PVC's miscibility with a variety of plasticizers. The flexible PVC form is often made from plastisols, which are suspensions of PVC in liquid plasticizers. Extensive use is made of PVC in building siding, piping, flooring, wall decorations, and water ducting. See **antimony trioxide; butyl epoxy stearate; chlorine; coating, water-borne system; dioxin; phonographic record; pipe, deteriorating; plasticizer, phthalic; polymerization, aqueous; rail-track protection; recycling steel with vinyl scrap; recycled carpet; test, Kling fusion; vinyl chloride monomer; vinyl composition tile; vinyl plastic; vinyl seagoing bag.**

polyvinyl chloride plastic, alloy There are various classes of these polyalloys. One is used to improve the impact resistance of PVC by blending with compatible rubbery plastics such as ethylene-vinyl-acetate, nitrile rubber, or chlorinated PVC.

polyvinyl chloride plastic, chlorinated By postchlorination, this thermoplastic increases PVC's glass transition temperature, heat-deflection temperature under load, chemical resistance, rigidity, flame retardance, tensile strength, and weatherability and reduces flammability and smoke generation. It is used in hot and cold water piping, chemical liquid piping and waste-disposal services. Also called *CPVC* or *PVD.*

polyvinyl chloride plastic fusion See **test, Kling fusion.**

polyvinyl chloride, plastic gelled PVC after the PVC particles have been fused under the combined influence of heat and pressure. See **gel.**

polyvinyl dichloride plastic (PVDC) A high-strength chlorinated PVC plastic. It is self-extinguishing and has superior chemical resistance. It can carry hot, corrosive materials. See **polyvinylidene chloride plastic.**

polyvinyl ether plastic Any of a group of vinyl ether plastics producing polyvinyl methyl ether, polyvinyl ethyl ether, or polyvinyl butyl oxide.

polyvinyl ethyl ether plastic A viscous gum to rubbery solid that is soluble in organic solvents. It is used as a pressure-sensitive adhesive tape. Also called *polyvinyl ether.* See **adhesive, pressure-sensitive.**

polyvinyl fluoride plastic (PVF) A thermoplastic that is commercially available as a film. It is a highly crystalline material with high toughness and flexibility, outstanding weatherability, high strength chemicals, oils, stains, and good abrasion resistance. Its useful properties are maintained over a temperature range of −70 to +110°C (−94 to +230°F). It is used in packaging (not for food) and electrical equipment.

polyvinyl formal plastic (PVF) A plastic in the PVAC group with excellent resistance to greases and oils.

polyvinylidene chloride plastic (PVDC) A thermoplastic that is derived by the polymerization of vinylidene chloride with lesser amounts of other unsaturated compounds, which results in a white powder that is used to produce products ranging from soft flexible to rigid plastics. Softening temperature is at 185 to 200°C (365 to 392°F). It is resistant to abrasion and chemical attack, impermeable to flavor, and possesses low vapor-transmission properties. Also called, *polyvinyl dichloride* or Dow Chemical's tradename *Saran.*

polyvinylidene fluoride plastic (PVDF) A member of the fluoroplastic family. Important properties include good tensile and compressive strength with high impact strength and chemical resistance. It is used in chemical equipment for gaskets, mixing impellers, and other pump parts; drum linings; and protective coatings. See **piezoelectric effect.**

polyvinyl isobutyl ether plastic (PVIE) An odorless elastomer that is insoluble in water and soluble in hydrocarbons, esters, ethers, and ketones. It is used in adhesives, plasticizers, and surface coatings.

polyvinyl pyrroldone plastic (PVPO) A highly polar and water-soluble plastic that is used in adhesives and as a water thickener. Water solutions can be used as blood plasma substitutes or artificial blood. See **blood; plastic, water-soluble.**

polyxylylene plastic See **xylylene plastic.**

population confidence interval The range of values of a population parameter computed so that the statement "the population parameter lies in this interval" will be true on the average, in a stated proportion of the times statements are made. See **A-basis; B-basis; S-basis; typical basis.**

population confidence level The probability that the true value lies within a stated range (the confidence interval). See **quality optimization goal.**

population confidence limit The limits on either side of a mean value of a group of observations that will, in a stated fraction or percent of the cases, include the expected value. Thus the 95% confidence limits are the layers between which the population mean will be situated in 95 out of 100 cases.

population parameter See **statistical population parameter.**

poromeric plastic A leatherlike structure that is permeable to air and water vapor. It is usually resistant to water penetration and abrasion. See **molding, flow; photoetching tool; polyester reinforced urethane plastic.**

porosity The formation of undesirable clusters of air bubbles and voids (trapped pockets of air, gas, or vacuum) within a solid material that includes on or near the surface of a fabricated product. For example, with film, numerous visible voids may be caused by open interstices into which either air or liquids may pass. See **air pocket, trapped; cavitation; corrosion resistance; dye; void.**

porous gel See **aerogel.**

porous metal A metal that is used in the manufacture of certain type molds or mold parts. For example, it can be used to permit removal of air from the mold cavities in injection molds or thermoformed molds. The material may require sealing. See **metal impregnation; mold porous; thermoforming mold.**

porous, micro- Having pores of microscopic dimensions. Some plastic films and fabric coatings are rendered microporous to permit breathing while retaining waterproofness. See **packaging, breathable-film; polyester reinforced urethane plastic.**

portland cement See **plastic-concrete composite.**

positron A positively charged particle having the same mass and magnitude of charge as the electron. Also called *positive electron.* See **radioactive beta particle.**

postconsumer plastic Plastic products that are generated by a business or consumer, have served their intended purpose, and have been separated or diverted from solid waste for the purposes of collection, recycling, and disposition. See **colorimeter; material, recovered; pellet color sorter; preconsumer; waste, postconsumer.**

postcuring See **curing, post-.**

postforming **1.** A process that is used to shape previously fabricated products such as thermoplastic extruded tubes, sheets, and films. Using the appropriate forming dies or molds, the forming is performed in-line after the extruder. Shapes include coils, twisted extrudates, embossing films or sheets, corrugated tubes, and decorative curved parts. See **design, corrugated; extruder postforming; extruder-blown tube forming. 2.** When forming is off-line, the process is generally identified as *thermoforming.* See **thermoforming. 3.** The forming, bending, or shaping of fully cured, C-stage thermoset plastic laminates or reinforced plastics that have been heated to make them flexible. On cooling, the formed laminates retain their contours and shape of the mold over which it was formed. Generally, only simple shapes are produced by this technique. See **bend, radius of; laminate, high-pressure formable.**

potentiometer An electrical control device that senses changes in voltage or a potential difference by comparison to a standard voltage and can transmit a signal to a control switch.

pot life The time that mixed plastics or plastic compounded with a catalyst, remains in a usable condition. It is measured at room temperature or the temperature to be encountered. This term should not be confused with *shelf life.* Also called *working life.* See **cure; shelf life.**

pot, molding See **transfer molding.**

potting 1. Embedding a component or assembly in liquid plastic where the mold remains an integral part of the product after the plastic is cured. The mold can be a shell or any can shape case. It is similar to encapsulation, except that it can be said that steps are taken to ensure complete penetration of all the voids in the object before the plastic polymerizes. See **casting; decorating; defoamer additive; embossing; encapsulation; exotherm. 2.** A method of imparting mechanical and insulating properties to a component such as electronic circuits, in which the component is deeply embedded and thoroughly impregnated with a casting plastic such as an epoxy. The plastic is normally degassed under vacuum to avoid air pockets. See **casting.**

pouch A type of container that is used to compete with blow-molded containers. Pouches are used to package products such as food, milk, water, and wine. See **packaging, retortable-pouch.**

pour-out finish See **container, pour-out finish.**

powder See **material, powder.**

powder, black Blasting powder or dynamite composed of potassium nitrate, charcoal, and sulfur composite; a blasting explosive that is made of nitroglycerin absorbed in a porous material and that at times contains ammonium nitrate or cellulose nitrate. This blasting powder has been compounded with plastics (injection molded, extruded, compression molded, etc.) to produce special devices used by the military and in commercial applications. See **cellulose nitrate plastic.**

powder blend See **compound, dry-blend.**

powder coating A solventless coating that is not dependent on a sacrificial medium such as a solvent but is based on the performance constituents of solid thermoplastic or thermoset plastics. It can be a homogeneous blend of the plastic with additives and fillers in the form of a dry, fine-particle-size compound similar to flour. Advantages of this process include its capability of minimizing air pollution as well as water contamination and increased coated part performance, resulting in cost savings. This is basically a chemical coating, so it has many of the same problems as solution coating or painting. If not properly formulated, the coating may sag at high thickness, show poor performance when not completely cured, reveal imperfections such as craters and pinholes, and have poor hiding with low film thickness.

Textiles, paper, and other flexible substrates such as fusible interlining, interlinking drapery and upholstered fabric, and carpets are examples of large volume applications. Another important market is with metals and other rigid materials. Included are plastics (pipes, tanks, screens, etc.) that can provide protective coatings using a variety of processing techniques. There are different coating techniques. The woven and nonwoven fabrics normally involve three steps as the cloth passes from the unwind roll to the rewind roll. Powder is metered onto the fabric, heated in an oven (gas or electric) that is usually divided into several heating zones, and cooled by a chill roll. Coating (plastics and metals) steps generally involve surface preparation, preheating substrate, powder applications, and postheating. Also called *fusion coating.* See **casting, centrifugal; coating, electrostatic spray; coating, flame spraying; coating, flood; coating, fluidized bed; coating, plasma; flocking; fluid-bed process; fusion; paint; pin hole; pollution, air; rotational molding; sag; solvent.**

powder compact See **material, powder compact.**

powder injection molding See **injection molding, nonplastic.**

powder metallurgy Powder is made by the atomization of liquid metals and is compacted in a die by the sintering process. See **metal; sintering.**

powder molding A general term that is used to denote several techniques for molding powders of varying sizes and shapes by melting plastic powders, usually against the inside of a mold cavity. The molds can be stationary or in motion such as rotation. See **casting; casting, slush-molding; compression molding; defoamer additive; density, apparent; encapsulation; injection molding; molding powder; rotational molding; vacuum hot pressing.**

powder rolling See **compacting.**

practice A procedure for performing one or more specific operations or functions that does not produce a result as compared to a fabricating process or test method. See **fabricating process; recommended practice; standard; test method.**

prebillow See **thermoforming, prebillow.**

precaution See **control-system reliability; reliability; troubleshooting.**

precipitate Material that is separated out of a solution in the form of a solid, by either physical or chemical means. See **acid rain; graphitization; pyrolysis.**
precipitation The deposition of a solid from a solution.
precision A concept of uniformity that is based on the magnitude of the random errors. The smaller the random errors, the higher is the precision. See **accuracy; deviation; error, random.**
precompounded See **compounded, pre-.**
preconditioning See **conditioning, pre-.**
preconsumer Any material that has not made its way to the consumer. It includes scrap, waste, and rejected parts or products. See **material, recovered; postconsumer plastic; waste.**
precursor The rayon, PAN, or pitch fibers from which carbon and graphite fibers are produced. See **carbonization; ceramic precursor, plastic; graphitization.**
preform **1.** A preshaped fibrous reinforcement of mat or cloth that is formed to the desired shape that will fit in a mold cavity. See **fiber mat; preform process. 2.** A compressed tablet or biscuit of plastic composition that is used for efficiency in handling and accuracy by the weight of its components. See **material handling. 3.** A plastic molding powder that is made into pellets or tablets. See **concentrate; pellet. 4.** Plastic preform is used for injection blow molding. See **blow-molding injection.**
preform process Preshaped fibrous reinforcements are formed by (1) the distribution of chopped fibers, usually glass fibers, by air, water floatation, or vacuum over the surface of a perforated screen to the approximate contour and thickness desired in the finished cured molded part; (2) the forming of mat or cloth to the desired shape on a mandrel or mock-up prior to being placed in a mold cavity, or (3) the use of a compact "pill" formed by compressing premixed material to facilitate handling and control of uniformity of charges for mold loading. See **felt; mat; reinforced plastic; reinforcement.**
preform process, plenum chamber Rovings or glass fibers are fed into a cutter and in turn into a plenum chamber. Deposits are made on a perforated screen as the air is exhausted from under the screen. A plastic binder of up to 5wt% is applied and later cured. See **fiberglass; roving.**
preform process, preform screen A screen that is used in the different preforming processes.
preform process, water slurry This method employs techniques that are similar to those used in the paper industry. Chopped strands, usually glass fibers, are slurried in water followed by a drying cycle. Cellulose fibers or plastic binders can be included to provide exceptionally strong structures. Fibers alone are tough and self-supporting. See **wet felting.**
pregel See **reinforced-plastic pregel.**
preimpregnation See **impregnation, pre-; reinforced-plastic preimpregnation.**
preloaded Containing or combined with the full complement of plastic before molding.
premolding See **reinforced plastic, premolded.**
preplastication See **plastication, pre-; plasticize.**
preply See **reinforced plastic preply.**
prepolymer See **polymer, pre-.**
prepolymer molding See **foam, prepolymer.**
prepreg A reinforcement containing or combined usually with a thermoset liquid plastic (thermoplastics are also used) that can be stored under controlled conditions. Reinforcement (such as fibers or rovings, woven or nonwoven fabrics, etc.) can be in different forms and patterns. The TSs are completely compounded with catalysts and partially cured to the required tack state in the B-state. The fabricator completes the cure with heat and pressure. See **A-B-C stages; debulking; directional property; doctor blade; fabric; impregnation; plastic heat staging; reinforced plastic prepreg; sewer rehabilitation; tack.**
prepreg molding See **reinforced plastic lay-up, wet.**
prepreg out time The time that a prepreg is exposed to ambient temperature, specifically the amount of time it is out of the freezer. The primary effects of too long an out time are a decrease in the drape and tack-free condition, as well as absorption of moisture from the air.
prepreg pucker See **reinforced plastic prepreg pucker.**
prepreg shop life The length of time that the prepreg remains usable at ambient temperature. A prepreg that has a storage life of six months at 0°C (32°F) might have only a three-day shop life.
prepreg solution process A solution (plastic and solvent) process that is used to provide a fast, continuous impregnation. The reinforcement goes through a solution tank that has a fixed or moving round bar to guide the reinforcement. The amount absorbed depends on factors such as the viscosity of the solution, thickness of the material, and line speed. After impregnation, it goes through a dryer to remove the solvent. See **reinforced plastic pultrusion; solution.**
prepreg tack control Tack is the adhesion characteristic that is controlled to facilitate lay-up operations. It is affected by type of plastic and inert volatile contents, prepreg cure advancement, and the lay-up room temperature and humidity. Prepregs with no tack are either excessively advanced or have exceeded their normal storage life, rendering the material useless. Certain plastics, such as silicones and some polyimides, can only be prepared with no tack.
prepreg tack primer A device that is used to hold dry or nontack prepreg together during a molding operation.
prepreg tape Unidirectional prepreg tapes are used in lay-ups or around a mold such as in filament winding. See **filament winding.**
prepreg terminology See **sheet-molding compound.**
prepreg, thermoplastic From the 1940s to about the 1980s, the only commercial prepregs were with thermoset plastics, and most TS polyesters continue to be the major

type used now. Thermoplastic prepregs are available and primarily used in stamping operations. See **stamping.**

prepreg volatile content Quality control tests do not distinguish inert from reactive volatiles, but they establish volatile content values that are important in processing prepregs. They provide qualitative evaluations of prepreg advancements, degree of volatilization of the solvents, and degree of degradation due to aging. Volatile contents measured prior to lay-up are compared against values when the prepreg was first received to detect any aging. See **quality control; volatile content.**

preprinting See **thermoforming, preprinting.**

preservative An agent that prolongs the useful life of a material. See **aging; antioxidant agent.**

press Presses range from parallel platens to book-opening platens. They can be used to provide pressure on molds or to laminate plastic materials, such as in injection molding, compression molding, and forming. See **clamping; clamping, hydraulic; platen.**

press, angle Horizontal and vertical hydraulic rams apply pressure for loading on a mold in a biaxial pattern.

press, automatic A hydraulic, electrical, or hybrid clamping press with controls so that it operates completely automatically, repeating fabricating cycles for injection, reaction injection, and compression molding machines.

press, block **1.** A press that is used to mold very large blocks, such as 8 ft^3 (0.2 m^3) of polystyrene plastic foam. See **foamed block. 2.** A press that is used for the agglomeration of laminate squares. See **laminate.**

press carousel See **press, rotary.**

press clave See **reinforced-plastic press clave.**

press, cold A bonding operation where an assembly is subjected to pressure without the application of heat. See **adhesive, cold-setting.**

press, double ram A press for injection and transfer molding in which two distinct systems create a different melt-flow pattern that differs from the usual independently operating machines. See **injection molding; melt flow; transfer molding.**

press, downstroke A press in which the operating main ram applies its pressure in a downward movement.

press fit See **fit, interference.**

press, floating punch A male mold member that is attached to the head of a press in such a way that it is free to align itself in the female part of the mold when the mold is closed.

press, gravity-closing In a down-stroke press, the closing motion is actuated by the weight of the ram and its associated parts only.

press, hydraulic A press in which force is created by the pressure exerted by fluids.

press, hydromechanical A press in which force is created by the combination of a mechanical system, such as a toggle mechanism, and a hydraulic system.

pressing, isostatic See **molding, isotactic; sintering.**

press, mechanical A press that is operated by mechanical power as opposed to hydraulic or electric power. Load is usually applied through a crank or toggle mechanism. See **clamping, toggle-action.**

press, molding A process that is used in different processes, such as compression molding, injection molding, and blow molding, utilizing a plurality of molds mounted on a rotating table. It is not to be confused with rotational molding. See **molding.**

press platen, book opening See **clamping platen, book-opening.**

press, punching A method of producing parts, such as electrical components and decorative displays, from materials, such as flat sheets or laminates, by punching out shapes using a die to provide the shape.

press, rotary A press that has a rotary or carousel movement. See **clamping platen, rotary.**

press, sliding punch A punch mounted in a press on rails to permit its withdrawal from the press between molding operations.

press stroke The length of ram travel on a press.

press table The lower table of a vertical press. In an upstroke press, it rests on the rim; in downstroke it is fixed in position and is attached to the basic casting or structure of the press.

press, tilting head See **clamping platen, book-opening.**

pressure A force or stress exerted on a particular area. The Pascal (Pa) is the pressure or stress of 1 Newton per square meter (N/m^2) or pounds per square inch (psi). There are different scales of pressure, such as absolute, gauge, and volume.

pressure, absolute A force that is equal to gauge pressure added to atmospheric 14.7 psi pressure at sea level. See **thermoforming, pneumatic control.**

pressure, ambient The pressure of a medium surrounding a product or object at ambient pressure.

pressure and heat transfer See **thermodynamic properties.**

pressure, atmospheric At various altitudes in feet, in approximate absolute pressure in psia (gauge: in. of Hg), they are sea level at 14.7 (0.0), 1,000 at 14.2 (1.0), 2,000 at 13.7 (2.1), 2,000 at 13.2 (3.1), 4,000 at 12.7 (4.1), 5,000 at 12.2 (5.0), and 6,000 at 11.7 (6.0). See **atmosphere; torr; vacuum.**

pressure bag molding See **reinforced plastic pressure bag molding.**

pressure, bar A metric unit of measurement of pressure. It has a dimension of unit of force per unit of area. It is equal to 1.0E + 06 dynes/cm^2 or 1.0E + 05 Pascal. It is used to denote the pressure of liquids (melts), gases, and vapors.

pressure blasting See **deflashing, pressure-blasting.**

pressure, blow See **blow molding; thermoforming.**

pressure, boiling At a specific temperature, the pressure at which a liquid and its vapor are in equilibrium.

pressure booster A device that uses a large volume of

low-pressure air or liquid (oil, etc.) to produce a low volume at high pressure. Also called *intensifier.*
pressure break See **laminate, pressure break.**
pressure, contact The force per unit area of physical contact between two surfaces. This term is frequently but improperly used when *contact force* is meant. The area of physical contact is usually difficult to determine and quite different from the apparent area of contact.
pressure control See **injection-molding nozzle-pressure control; thermoforming, pneumatic control.**
pressure, critical The pressure at which liquefaction occurs at the critical temperature.
pressure-detecting film A film that is used to determine compression magnitude and distribution between contact surfaces. When subjected to pressure, the film turns a shade of red, the intensity indicates actual applied stress. A calibrated color-density chart quickly provides the pressure magnitude. This technology is based on a controlled chemical reaction. Tiny, uniform microcapsules embedded in the film rupture at specific stress levels, depending on the film grade used. Applications include equipment using rolls, presses, or stamping.
pressure differential See **venturi.**
pressure flow Controlling and repeating melt-pressure flow in processing machines is critical to their operation. There are different factors to consider when operating the machines. See **flow model; flow, Poiseuille; melt flow; venturi; viscosity, Hagen-Poiseuille law of; viscosity, Newtonian flow; viscosity, non-Newtonian flow.**
pressure, foam See **test, foam pressure.**
pressure forming See **forming, stretch and draw ratios for pressure; thermoforming, pressure.**
pressure, gauge The pressure measured from a pressure gauge that starts at zero (0) psi. The 0 pressure is equivalent to atmospheric pressure; at sea level it is 14.7 psi.
pressure gas test See **test, soap-bubble.**
pressure, holding See **injection-molding holding pressure.**
pressure, hydrostatic **1.** Pressure applied by means of a fluid. **2.** A state of stress in which all the principal stresses are equal and there is no shear stress. See **modulus, bulk.**
pressure, injection-molding See **injection molding mold-cavity pressure; molding pressure, required.**
pressure intensifier See **reinforced plastic pressure intensifier.**
pressure, Lavell A ratio of the melt pressure and gas pressure that is less than 0.5, so that undesirable turbulence of the melt can be expected. See **injection molding, gas-assist.**
pressure, line The pressure under which an air or hydraulic system operates.
pressure loader/conveyor See **material handling, pneumatic loader and conveyer.**
pressure, locking In molding (injection, transfer, etc.), the pressure that is applied to the mold to keep it closed, in opposition to the fluid pressure of the compressed molding material. See **compression molding; injection molding; reaction injection molding; transfer molding.**
pressure measurement See **clamping pressure measured.**
pressure, negative See **vacuum.**
pressure, partial The pressure of each component in a mixture of gases.
pressure, standard-state The condition of one atmosphere of pressure. See **atmosphere.**
pressure temperature See **process control.**
pressure, vacuum Negative pressure, that is, below atmospheric pressure. See **thermoforming, pneumatic control; vacuum.**
pressure, vapor See **vapor pressure; volatile.**
pressure, volume It is expressed in cubic feet per pound (ft^3/lb) or m^3/kg. However, volume measurements can differ because gas expands and contracts with changes in temperature and pressure. Volume is measured easily by using the inverse of specific volume, which is density (D).
pretreatment, decorating See **decorating pretreatment.**
preventing waste See **recyclable.**
price See **cost.**
primary equipment See **fabricating processing type.**
primary processing equipment See **fabricating process.**
primer A substance that is used for preparing surfaces for adhesives and coatings. For example, in adhesive bonding, a reactive chemical species is dispersed in a solvent that is applied to the part surface by spraying or brushing. After the solvent is flashed off, the part surface may be bonded immediately, as in polyolefin primers for cyanoacrylates, or may require time to react with atmospheric moisture, as in silane and isocyanate-based primers. Primers usually contain a multifunctional chemically reactive species that is capable of acting as a chemical bridge between substrate and adhesive. They are commonly used with acetals, fluoropolymers, polybutylene terephthalates, silicones, polyurethanes, and polyolefins. In coatings the primers are used on the substrates to improve the adhesion of the topcoat, seal pores (if they exist), improve corrosion protection, or hide surface defects or color. Also called *adhesive promoter.* See **adhesion promoter; coating, air-drying alkyd plastic; decorating pretreatment; lacquer coating; paint.**
printed circuit board (PCB) A board with usually copper-clad laminates using thermoplastics or thermoset plastics. The clad is etched to produce an electrical or electronic circuit pattern (components) on one or both sides. It serves as a means of electrical interconnection and physical attachment for the printed circuit. Also called *printed board, electrical circuit board,* or *printed wire board.* See **artwork, photoplotter; electrostatic discharge detector; injec-**

tion molding circuit board; laminate, copper-clad; printing, screen.

The traditional method of mounting components on printed circuit boards is known as *through-hole technology*. With through-hole technology the wire leads of components are bent perpendicular and inserted through the PCB molded or drilled holes and then soldered in place. With surface-mount technology, the leads of the components do not pass through the PCB; instead, the leads are bent parallel to the surface of the PCB and soldered to pads on the surface. To create the solder joint, a solder paste is applied to the board using screen printing or stenciling process. After applying the solder paste, the components are placed on the board and then heated in an oven to cause the solder to melt and form the joint. SMT components are typically much smaller and lighter than corresponding conventional components, making possible the much higher component densities and smaller product sizes required by portable computers, cellular telephones, and similar devices. Consequently SMT accounts for over 50% of all PCB manufacturing. See **injection-molding circuit board; printing, screen.**

printer drive system See **control drive, optimized.**

printing A method for decorating and marketing plastic parts by means of various printing processes, such as gravure, flexographic, inlay (or valley), offset, screen, letterpress, electrostatic, and photographic methods. Printing machinery and special inks have been developed to meet the special requirements and surface problems of various plastics. See **control drive, optimized; decal; decorating; graphic art; laser marking; printing, photography and photomechanical; photopolymer.**

printing, Acrobot A tradename for a device introduced by Permanent Label Corp., Clifton, NJ, in 1984. It robotically turns a part while it is being printed, allowing products with circular, elliptical, or round-polygonal cross-sections to be decorated by screen printing and heat transfer printing. See **decorating; printing, heat-transfer; printing, screen.**

printing and varnish Varnish is a variety of ink. It is clear or tinted, glossy or dull, and behaves on a press much like ordinary inks. It can make a sheet sparkle or give it a smooth and satiny finish. See **printing ink; varnish.**

printing/coating, offset A technique in which ink is transferred from a batch (reservoir) onto the raised surface of the printing plate by rollers. Subsequently, the plates transfer the ink to the part being printed (or coated). The distinguishing feature of this printing method is the offset roll. Dry, pasty inks are used. This method is widely used with plastic products.

printing contact pattern See **Fresnel diffraction pattern.**

printing dot See **printing, electronic dot generation.**

printing electronically Any technology that reproduces pages without the use of traditional ink, water, and chemistry. Most often this is accomplished by laser, electrostatic, or electrophotographic, devices.

printing, electronic dot generation (EDG) A method of producing halftones electronically on scanners and prepress systems.

printing, electrostatic charged area development (CAD) A process in electrostatic copying where the photoconductive element is charged with the opposite sign of the toner. A light source is used to discharge all areas on the photoconductor that are not to receive the toner to form the image.

printing, flexographic A method suitable for printing on plastics. It is basically a letterpress process since it prints from a raised image. It employs a hard metal plate instead of a soft and rubbery plate. See **coating, solution.**

printing fluoroplastic See **surface CASING.**

printing, gravure The depositing of ink on plastic film, sheet, or products from depressions of a specific depth, pattern, and spacing that have been mechanically or chemically engraved into a center or roll. The impression cylinder is covered with an elastomeric composition that presses the sheet (being printed) into contact with the ink in the tiny cells of the printing surface. The depth of the overall engraved pattern principally controls the amount of coating applied. It is capable of applying finely detailed patterns in one or more colors on a continuous web at high speeds by direct or reverse printing. Also called *gravure roll coating* or *gravure coating*. See **printing, pad-transfer; roll.**

printing, gravure offset A method that is used to print patterns or designs, such as wood grains, on various products, such as plastic films and wall panels. A converted flexographic press is used. A gravure image cylinder and doctor blade for printing the image replaces the anilox roller, and the plate cylinder of the flexographic press is covered with a solid rubber plate.

printing, heat-transfer Printing that is done separately on film, foil, or foil and then transferred to the part that contains a recess. The recess should be shallow, and sufficient clearance is required for a heated die. Multicolor effects are readily achieved with this process. See **decal; printing, Acrobot.**

printing image See **printing, electrostatic charged area development.**

printing ink A viscous to semisolid suspension of finely divided pigment in a drying oil such as heat-bodied linseed oil. Alkyd, phenolic, and other plastics are used as binders. Cobalt, manganese, or lead soap is added to catalyze the oxidative drying reaction. Radiation curing systems are also used. Some dry by evaporation using volatile solvents. In the past most of the inks were not biodegradable. See **dye toner; environmentally acceptable coating, ink, adhesive reliability; ion-beam surface modification; plasma arc treatment; printing and varnish; printing ink; recycled paper; surface treatment.**

printing ink, radiation A method that eliminates powder in sheet-fed printing and air pollution from solvents in conventional web heat-set inks. There are two types: ultraviolet and electron beam inks. UVs consist of liquid prepolymers with initiators that, on exposure to large doses of UV radiation, release free radicals that polymerize the vehicle to a dry, solid, tough thermoset plastic. Due to their expense, they are used in luxury packaging. EBs provide a good alternative to UVs since no expensive initiators are needed. Their main disadvantage is the high cost of equipping a press, but they use less energy than UVs and about half the energy of gas drying. See **cross-linking; electron beam treatment; ultraviolet radiation.**

printing ink transfer, sublimable See **dye transfer, sublimable.**

printing ink, transparent An ink that does not conceal the color beneath. These plastic inks are transparent, so they blend to form other colors.

printing, lithographic resist A process that is used in most commercial printing applications and is based on a simple inking and noninking system. A plastic image is formed by masked exposure to light, followed by the dissolution of the unwanted plastic. The plastic absorbs ink, and the substrate rejects it. The ink image is then transferred to the product to be printed. These photosensitive plastics are also used on printed circuit boards, and microwave chips. See **photopolymer; printing, photolithographic technique.**

printing, pad-transfer A transfer system that is an offset, or indirect, gravure process. The quick drying (within seconds) solvent-based ink is applied in excess over an engraved steel image plate, called a *cliché*. A doctor blade, leaving the ink only in the engraved recesses, removes the excess. A soft silicone rubber pad picks up the ink from the cliché and transfers it to the plastic part to be printed or decorated. It is exceptionally suitable for printing irregular shaped or rough surfaces as well as soft, flexible products such as squeeze blow-molded bottles. See **decorating; printing, gravure.**

printing, photoengraving Photoengraving has experienced some of the biggest technological beneficial upheavals in the graphic arts industry. Having gone from the engraving of zincographs to the exposure of films first by camera and then by laser beam, it has become one of the most sophisticated branches of the graphic arts industry and requires a highly skilled staff. Scanners, studio and electronic image processing, and desktop publishing are widely used. Photoengraving products include offset plastic films, offset and gravure printing, and letterpress plates (zinc or nylon blocks showing in relief the image or text elements to be printed using the letterpress process). See **graphic art.**

printing, photography and photomechanical Photography involves the photographic processes and techniques that are used to produce illustrations and art subjects. Photomechanics or photoplating—including photoengraving, photolithography, photogelatin, and photogravure—uses the products of photography, like halftones and line films, to make plates and cylinders for printing. See **photopolymer; printing, screen.**

printing, photolithographic technique Lithography in which photographically prepared plates (plastics, etc.) are used. See **printing, lithographic resist.**

printing, photomechanical coating A phase of the photomechanical process that causes changes in physical properties after exposure to light. Usually the exposed areas change in solubility in water and other solutions. In the past, natural organic materials (asphalt, shellac, albumin, gum arabic, etc.) were used as ingredients of the coatings. Synthetic plastics such as polyvinyl alcohol and photopolymers are now used. See **photopolymer.**

printing pica A printer's unit of measurement that is used principally in typesetting. One pica equals about $^1/_6$ in. (4.2 mm).

printing plate See **photopolymer.**

printing polyethylene See **surface CASING; surface treatment.**

printing, pre- See **cut, kerf, and registration; thermoforming, preprinting.**

printing, roll-leaf A method that is used to produce small designs on films. It involves the transfer of dry ink by heat and pressure from a carrier to the film. It is a marking method sometimes used for intricate parts, such as terminal blocks. Also called *roll-leaf coating, roll-leaf stamping,* or *hot stamping.*

printing, roll-on A method that uses machines to advance preprinted heat transfers and conventional hot-stamping foils. See **coating; stamping, hot.**

printing, rubber plate A marking method sometimes employed for intricate parts such as molded terminal blocks.

printing, screen A hand operation that can be used when only a few products are to be printed or decorated using very simple equipment consisting of a table, screen frame, ink (applied over the screen), and squeegee. Most commercial screen-printing is done with power-operated presses. Two types are used: one uses flat screens that require an intermittent motion as each is printed, and the other uses a fast continuously rotating screen with the squeegee mounted inside the cylinder. The amount of ink applied is far greater than in a letterpress, lithography, or gravure, which accounts for some of the unusual effects in screen-printing. Heat driers can be used for drying ink; however, for the fastest cleanest operations, ultraviolet-curing inks are used. Masking materials are used to block out unwanted areas. See **barcode; decal; photopolymer; printed circuit board; printing, Acrobot; printing, photography and photomechanical; silk-screen printing.**

To obtain the desired print pattern from a photo image, parts of the screen must be blocked. For example, the photoimage process is important for screen-printing-type stencil making. A photosensitive plastic emulsion is applied over the screen, and parts of it are exposed to light through a positive image of the artwork. Exposed areas become insoluble, and the remainder of the emulsion is removed by washing. Ink passes through the nonemulsion photoresist areas. Precast photosensitive plastic films are available and provide a coating of uniform thickness. Such a film is laminated to the screen and processed in a similar way as the direct emulsion coating. See **artwork; emulsion; printed circuit board.**

printing signature In printing and binding, the name given to a printed sheet after it has been folded.

printing surface See **plasma arc treatment; surface treatment.**

printing, thermoformed See **thermoforming, preprinting.**

printing, thermographic transfer A modification of the hot stamping process wherein the design to be transferred is first printed on a film, from which it is transferred to the plastic part by means of heat and pressure.

printing, valley A process that provides three-dimensional texturing with surface coloring by simultaneously embossing and printing on preheated plastic. It is usually done in only one color on a material of contrasting color to create two-color, three-dimensional effects. Ink is applied to the high points of an embossing roll and subsequently deposited in what becomes the valleys of the embossed plastic material. Also called *inlay printing.*

printing, xerography A dry method of photography or photocopying that is named for the copy machine introduced by Xerox Corp. It is an electrophotographic copying process. Plastics have been used in place of sulfur photoconductor and lycopodium toners in xerography. Present-day toners are plastics that may be thermoplastic homopolymers or copolymers that are cross-linked to achieve different desired fusing characteristics. For example, halogenated homopolymers and copolymers are used to give carriers a negative charge, and copolymers of polystyrene-alkylmethacrylates and acrylates are used to give carriers a positive charge.

probability Likelihood, chance, tendency. From a practical approach, as it applies to the statistical mathematical determinations that are made to estimate quality control. See **quality control; reliability; statistical estimation; statistical phase/reasoning; statistical probability, six-sigma.**

problems and solutions Potential problems can be predicted by considering the relationships of machine capabilities, plastics processing variables, and product performance requirements. Equipment and plastic may lack necessary capabilities. A distinction between machine conditions and processing variables must be made to avoid mistakes and to use cause-effect relationships to their best advantage.

A logical and systematic method of dealing with variables or problems is required to resolve them. The method should use language that everyone understands. Terms and phrases cannot be ambiguous and cannot have multiple definitions. It may be important to include what a term does not mean to eliminate any misunderstandings. If it is necessary to include engineering equations or chemical formulas, they must be explained in terms understood by technical and nontechnical workers.

When the specific problem has been identified, its solution needs to be recorded, preferably in the operating manual that is used in operating the production line. If applicable, the information should be included directly into the line's process control system. Unfortunately, at times Chisolm's law sometimes is followed. According to this law, if at times things appear to be going better, you have overlooked something. By analyzing failures, reverses can become a route to eventual success. Even a quick postmortem on a project that has foundered may prevent a future failure. See **algorithm, generic; computer processing control automation; control-system reliability; cybernetics; DART software; debug; design-failure theory; hypothesis; plastic failure or success; plastic product failure; reliability; statistical benefit; statistical quality control; statistical randomization; troubleshooting guide.**

process A fabricating method or production line. See **fabricating process.**

processability The relative ease with which raw material (virgin or recycled plastics) can be processed into products. See **material; plastic.**

processability and molecular weight Processability is best when the plastic is at low MW, while properties of the finished product are best at high MW. Molecular weight distribution should be as narrow as possible to make plastics process easier with properties of the product more uniform. See **molecular weight; molecular-weight distribution.**

process control Adequate process control and its associated instrumentation are essential for product control. Sometimes the goal is precise adherence to a control point; other times it is maintainance of control within a comparatively narrow range. For effortless controller tuning and lowest initial and operating cost, the processor should select the simplest controller (temperature, time, pressure, flow rate, etc.) that will produce the desired results. For the complete line, controllers can range from unsophisticated to extremely sophisticated devices.

Controls (1) provide closed-loop control of temperature, pressure, and thickness; (2) maintain preset parameters; (3) monitor or correct equipment operations; (4) constantly fine tune equipment; (5) provide consistency and repeatability in the operations; and (6) provide self-optimization of the process. Most processes operate more efficiently when functions must occur in a desired time sequence or at prescribed intervals of time. In the past, mechanical timers and logic relays were used. Now electronic logic and timing devices are used based on computer software programmable logic controllers. They lend themselves to easy set-up and reprogramming. See **computer batch processing; computer continuous pro-**

cessing; computer, microprocessor control; computer software; control; controller; designing processes with models; device, smart; fabricating process; FALLO approach; injection molding, boost cut-off or two-stage control; injection-molding process control; intelligence, artificial; melt-flow analysis; processing, intelligent; processor, micro-, control; production-control system; productivity; quality control; rheometer; sensor; servo control; statistical quality control; temperature proportional-integral-derivative.

Most process-control units provide independent control loops and usually control only one major variable. A few interact with different variables, so the operation of a complete line requires the skill of an operator. However, the available controls properly installed and used have been extremely useful to operators by simplifying the setting-up, operating, and shutdown of the line.

Lines operate with different degrees of automation via computer-integrated controls, providing improvements in operating procedures and quality assurance and reductions in costs. These closed-loop systems maintain long-term repeatability of factors such as melt velocity and pressure. This action occurs independently of what could be occurring with component wear, unbalanced equipment in the line, or plastic material variations.

Usually elaborate control systems cannot correct for problems such as those caused by a (1) worn screw and barrel, (2) inadequate drive torque, or (3) poor screw design. For example, such systems will not yield good temperature control unless all features essential to good control are well maintained. Burnt-out heating elements cannot be tolerated. Another common deficiency for liquid-cooled extruders is fouling or restrictions in the plumbing system or inoperative valves. Other factors of these types also exist.

process control, adaptive A control system that changes settings in response to changes in machine performance to bring the product back into specification. The control adapts to changing conditions. It is a technique typically used to modify a closed-loop control system. See **computer processing control automation.**

process control, blow molding parison See **blow molding, extruder, parison programmed-control.**

process control comparator The portion of the control elements that determines the feedback error on which a controller acts.

process control, computer Computer controls range from simple to complex systems that meet different requirements for the processors. Computer type depends on the control needs including required profitability improvements. Continual changes need to be addressed by control programmers and data acquisition systems. See **computer processing control automation.**

process control, control-loop The signal circuit that provides feedback information for closed-loop process control. See **servo control.**

process control cooling rate See **mold cooling rate.**

process control decision See **computer monitoring information.**

process control die-orifice modulation See **blow molding, extruder, parison programmed-control.**

process control, fabricating influence See **test specimen.**

process control, fuzzy logic See **control, fuzzy-logic.**

process control measurement See **transducer.**

process control melt flow See **rheometer, capillary.**

process control mold parting line See **injection-molding process-control parting line.**

process control motion See **design, motion-control, mechanical and electronic effects.**

process control optimization See **control drive, optimized; repeatability.**

process control, roll nip See **calendering, controlled nip pressure in; nip.**

process control simulator See **process simulator.**

process control startup and shutdown See **fabricating startup and shutdown.**

process control, statistical See **computer processing control, statistical; statistical process control.**

process control, temperature zone See **screw temperature zone.**

process control, trial and error See **computer processing control automation; problems and solutions.**

process control variable See **motion-control system.**

process control window See **molding area diagram; molding volume diagram; processing window.**

processing See **computers and statistics; control; fabricating process; microprocessor control; plastic failure or success.**

processing agent An aid, agent, or medium used in the manufacture, preparation, and treatment of a material or article to improve its processing or properties.

processing and color See **color stability and processing.**

processing, art of Processing plastic is an art of detail. Attention to details reduces problems with the process. Note that a process will continue running well unless a change occurs. Correct the problem, but do not compensate. When making processing changes, allow enough time to achieve a steady state in the complete extrusion line before collecting data. It may be important to change one processing parameter at a time. For example, with one change, such as extruder screw speed, temperature zone setting, cooling roll speed, blow-film internal air pressure, or another parameter, allow four time constants to achieve a steady state prior to collecting data. Equipment, material, environment, and people need to be attended to. See **ergonomics; FALLO approach; maintenance; troubleshooting.**

processing defect A structural or other defect in material or a part that is induced inadvertently during manufacture of the material or during processing. At fault could be factors such as the wrong additives or ingredients, tooling, processing conditions, or part design. Usually defects are preventable. Also called *processing flaw*. See **defect.**

processing diagram See **molding area diagram; molding volume diagram; processing window.**

processing feedback **1.** Information that is returned to a system or process to maintain the output within specific limits. **2.** The information in machine or processing learning that the program receives about the correctness of the choices it makes.

processing failure See **failure, fault-tree analysis; problems and solutions.**

processing fundamental See **art and science; catalyst type; design success; design constraints; design-failure theory; design, innovative; design, material optimization; design safety factor; die; fabricating process; melt; mixing; mold-cavity melt-flow analysis; molecular-weight distribution; morphology; polymerization; rheology; shear stress; viscoelasticity.**

processing high-molecular-weight plastic See **detonation.**

processing improvement New developments with equipment and plastic materials usually result in improvements in processing capabilities toward meeting goals of zero defects as well as to reduce costs. See **barrel grooved feed; carbon dioxide.**

processing, in-line A complete fabricating or production operation can include material storage and handling, production of the part, upstream and downstream auxiliary equipment, inspection and quality control, packaging, and delivery to destinations such as warehouse bins or transportation vehicles. See **auxiliary equipment; fabricating; fabricating process type; inspection; material handling; packaging; processing line, downstream; processing line, upstream; quality control; storage; warehousing.**

processing, intelligent (IP) Cutting inefficiency and in turn cutting the costs associated with them. Intelligent processing of materials utilizes new sensors, expert systems, and process models that control processing conditions as materials are produced and processed without the need for human control or monitoring. Sensors and expert systems are not new but are being tied together in a novel manner. In IP, new nondestructive evaluation sensors are used to monitor the development of a material's microstructure as it evolves during production in real time. These sensors can indicate whether the microstructure is developing properly. Poor microstructure will lead to defects in materials. In essence, the sensors are inspecting the material on-line before the product is produced. See **intelligence.**

The information these sensors gather is communicated, along with data from conventional sensors that monitor temperature, pressure, and other variables, to a computerized decision-making system. This decision-maker includes an expert system and a mathematical model of the process. The system then makes any changes necessary in the production process to ensure that the material's structure is forming properly. These might include changing temperature or pressure or altering other variables that will lead to a defect-free end product.

A number of benefits can be derived from intelligent processing. There is, for instance, a marked improvement in overall product quality and a reduction in the number of rejected parts. And the automation concept that is behind intelligent processing is consistent with the broad, systematic approaches to planning and implementation being undertaken by industries to improve quality. Intelligent processing involves building in quality rather than attempting to obtain it by inspecting a product after it is manufactured. Thus, it allows industry to reduce postmanufacturing inspection costs and time. Being able to change manufacturing processes or the types of material being produced is another potential benefit of the technique.

processing line, downstream The plastic discharge end of the fabricating equipment, such as the auxiliary equipment in an extrusion pipe line after the extruder. See **fabricating process; processing, in-line.**

processing-line downtime The period when equipment cannot operate when it should be operating. Downtime may be caused by equipment being inoperative, a shortage of material, an electric power problem, operators who are not available, and so on. Regardless of its reason, downtime is costly. See **injection-molding machine maintenance; maintenance; troubleshooting.**

processing line, upstream Material movement and auxiliary equipment (dryer, mixer/blender, storage bins, etc.) that exist prior to plastic entering the main fabricating machine, such as the extruder. See **fabricating process; processing, in-line.**

processing-line uptime The period when the plant is operating to produce products.

processing model See **designing processes with models.**

processing parameter A measurable variable, such as temperature and pressure, that is required during the preparation of plastic materials, processing of products, or inspection.

processing plant, automated See **computer-automated laboratory to production; automation level.**

processing practice See **quality-system regulation.**

processing, reaction viscosity The design of conventional (nonreactive) plastic processing equipment is complicated by the non-Newtonian nature of plastic melt viscosity. When attempting to design equipment to process reactive fluids, one is faced with an even more formidable task—accounting for changes in viscosities with conversions, temperature, and molecular weight, as well as nonuniformities within equipment. Difficulties can be experienced when attempting to mix or pump polymerized fluids with rapidly rising viscosities that accompany the reaction. To understand the associated flow phenomena, it is necessary to deal with the coupling between extent of reaction and viscosity. Reaction viscosity is much more sensitive to concentration and molecular weight than to temperature and shear rate. See **melt flow; molecular weight; viscosity, non-Newtonian flow.**

processing rules Rules to remember: (1) Processing is a marriage of machine, mold or die, material, process control, and operator all working together; (2) the plastics business is a profit-making business, not a charitable or nonprofit government organization; (3) heat always goes from hot to cold through any substance at a controlled rate; (4) hydraulic fluids or electric drives are pushed, not pulled, at a rate that depends on pressure and melt flow; (5) the fastest cycle or rate of output that produces the most products uses (a) minimum melt temperature for fast cooling, (b) minimum pressure for lowest stress in products, and (c) minimum production time; and (6) all problems have a logical cause: understand the problem, solve it, and then allow the machine to equalize its production to adjust to the change; and (7) if it does not fit, do not force it.

Rules to forget: (1) The machine has a mind of its own; (2) it takes a genius to operate a machine; (3) all problems are caused by bad part design, bad tooling, or bad setup; (4) my job is secure; (5) if a little bit does a little good, a whole lot does a whole lot of good; and (6) if you twist enough knobs, the problem will go away.

processing stabilizer In thermoplastics, a substance that acts in the same manner as an internal lubricant by plasticizing the outer surfaces of the plastic particles and easing their fusion but that can be used in greater concentrations (about 5 pph). With thermoset plastics they are not reactive normally and therefore reduce the rate of interactions of reactive groupings by a dilution effect. Thus easier processing may be derived mainly from the reduction in the rate at which the melt viscosity increases. At the same time the overall cross-linking density is reduced. Also called a *flow promoter.* See **stabilizer.**

processing startup and shutdown See **fabricating startup and shutdown.**

processing via fluorescence spectroscopy Sensor techniques can measure the properties of plastics during processing. The intent is to improve product quality and productivity by using molecular or viscous properties of the melt as a basis for process control, replacing the indirect variables of temperatures, pressure, and time. This system analyzes the fluorescence generated in the plastic during processing and translates it into a numerical value for the property being monitored. The plastic must be doped with a small amount of fluorescent dye specific to the application. An optical fiber installed in the plasticator barrel, mold, or die scans the plastic. It is used to perform other tasks, such as measuring the concentration and dispersion uniformity of filler. Accuracy of 1% provides a means of optimizing residence time. It can also monitor the glass transition temperature. See **glass transition temperature; residence time; spectrograph, x-ray fluorescence.**

processing window The range of processing conditions, such as melt temperature, pressure, and shear rate, within which a specific plastic can be fabricated with acceptable and optimum properties by a particular fabricating process. It is a defined area in a processing-system process-control pattern. This window for a specific plastic part can vary significantly if changes are made in its design and the fabricating equipment used. See **fabricating process type; mold gate, valve; molding area diagram; molding volume diagram; process control.**

processor There are basically three types of processor—captive, custom, and proprietary. See **fabricating; processor, captive; processor, custom; processor, proprietary.**

processor and competition The goal of the Mid-Atlantic Plastics Partners Inc. (MAPP) in Indianapolis, IN is to improve cost reductions, increase sales, solve technology and other problems, and develop human resources. See **cost reduction.**

processor, captive The in-house operation of a company that has acquired plastics processing equipment to make the parts it needs for the product they manufacture. For example, a refrigerator manufacturer may acquire a complete extrusion line to produce sheet and also acquire a thermoformer to produce the completed inner-door liners.

Generally speaking, these manufacturers will install a captive operation when their component requirements are large enough to make it economical (or when a secret product or process exists). Some manufacturers who run their own plastics fabricating lines will nevertheless place a portion of their requirements with outside vendors to keep their own capital investment down, to avoid internal single-source supply, to maintain contact with the "outside world" and the pricing intelligence it provides, and so on. The vendor could be a custom processor or a captive operation for their requirements. Some captive operations do not keep up with new developments critical to their operation. Also called a *captive fabricator.*

processor certification National skills certification programs are offered by various organizations worldwide to certify the skills and knowledge of the plastics industry processor machine operators. SPI's National Certification in Plastics (NCP) program (1) identifies job-related knowledge, skills, and abilities; (2) establishes a productive performance standard; (3) assesses and recognizes employees who meet the standard; and (4) promotes careers in the plastics industries. The examination includes basic process control; prevention and corrective action on primary and secondary equipment; handling, storage, packaging, and delivery of plastic materials; quality assurance; safety; tools and equipment; and general knowledge. Such programs are for plastics professionals who have the knowledge and ability to apply mathematics, the physical sciences, and engineering principles and methods to technological problem solving. See **inspection; ISO-9000 certification; ISO-14000 certification; productivity; test certification.**

processor, contract See **legal matter: processor contract.**

processor, custom The custom processor's operations, like those in the metal-working field, sometimes are known as *job shops,* which process plastics into products or components used in other industries. For example, a manufacturer of refrigerators could retain a custom processor to extrude sheets and thermoform the sheets into inner-door liners. Custom processors typically have a close relationship with the companies for whom they work. They may be involved (to varying degrees) in the design of the product and the die, they may have a voice in material selection, and in general they assume a responsibility for the work they turn out. See **business toll; legal matter: processor contract.**

processor, custom-contract A subgroup in custom processing known as contract fabricators who have little involvement in the business of their customers and just sell machine time.

processor, micro- A computer system that stores, analyzes, and adjusts the controls of a fabricating or manufacturing line based on parameters established during start-up to meet product performance and cost requirements. It has different capabilities such as operating within set limits for various functions, maintaining output rate, troubleshooting, storing operating data, and conducting cost analysis. See **computers.**

processor, micro-control Microprocessor control is anything from a sophisticated temperature controller to a full-blown fabricating line control. Because of the vast range of computer control and monitoring options available, selecting what is needed requires specifications on what is truly required to realize a return on investment. See **process control.**

processor, proprietary A processor who makes a product for sale directly to the public or to different companies, usually with its own tradename.

process planning See **computer-aided process planning.**

process simulator Software programs can simulate the operation of equipment that is processing plastics. They provide a logical approach in training and conducting research. For example, a software program can simulate the molding of different part designs with an injection-molding machine using different types of plastics. The simulated process controls permit the operator to make changes and see the effects that occur on a molded part, providing useful information including a troubleshooting guide. See **education; injection molding; melt-flow analysis; process control; research and development; training; troubleshooting.**

process validation See **ISO-9000 certification; quality-system regulation.**

product See **durable goods; gross domestic product; market; nondurable; goods.**

product acceptance See **test, organoleptic.**

product condition See **reliability.**

product defective analysis See **quality level, acceptable.**

product development See **revolutionary versus evolutionary developments.**

product downgrade Reduction in performance or other characteristics.

product, from raw material to See **plastic products, raw material to.**

production bill of material (BOM) A listing of the quantity of all materials, subassemblies, and other products required to produce one assembled product line.

production budget base The number of hours, machine or labor, that are required to meet an anticipated volume level.

production-capacity overhead rate A manufacturing overhead hourly rate based on practical capacity volume of an operation. See **business bookkeeping; capital equipment investment; machine-hour rate.**

production capacity plan The production hours required to produce an order and the total capacity required to produce all parts.

production-capacity utilization The degree to which facilities are used. It is usually measured in terms of a percentage of total capacity.

production-control system (PCS) The successful manufacture of a product involves (1) an efficient production process, (2) high quality or performance of the product, and (3) prompt delivery dates. A production planning and control (PPC) system has to cope with PCS requirements such as economic efficiency, just-in-time delivery, and saleability. General PPC systems are offered within the scope of commercial electronic data processing programs for the operational sequences. See **fabricating process; just-in-time; manufactured cost; process control.**

production data acquisition (PDA) The basic building block for computer-aided production or computer-integrated manufacture. It assumes a central role as the link between logistic information flow (production planning and control) and technical information flow. PDA makes it possible for all operating areas to achieve optimal performance of their tasks on the basis of solid current data. A logical product sales analysis requires a cost-effective, fault-free capture of all complete operating data and its detailed presentation in real time. See **computer electronic document and retrieval system; computer monitoring information; electronic data interchange; engineered, re-; fabricating process; plant operation; productivity; technology assessment.**

production order point An inventory quantity. When the available quantity falls to or below this level, the need to issue a replenishment order is indicated. Also called *reorder point.* See **inventory; warehousing.**

production order quantity The quantity of a material or product to be ordered or produced. Also called *lot size.* See **purchase order.**

production output See **fabricating output.**

production overrun analysis A technique for determining economical production quantities for products that are shipped infrequently.

production pegging Identification of the source of a need for materials or parts such as the customer name, order number, or assembly production order.

production performance A vital step in product design is to determine if the product will be capable of performing the task for which it is being designed and what level of safety factor is available. This requires analysis or testing. Most analysis focuses on the mechanical load-bearing function for both tensile and compressive stresses. Valuable design equations are available in standard texts on designing with plastics and reinforced plastics, and the mechanics of materials can often be applied based on the product geometry. They can yield excellent predictions of short-term (dynamic) loading capabilities, as well as long-term (creep-related) approximations. A key factor is to anticipate the extremes of temperature that can be encountered, especially high temperatures. Generous safety factors may be required to compensate for a variety of factors that can reduce the allowable load under extreme operating conditions. See **cost, carrying; creep; design safety factor; fabricating process; load; performance prediction; plastic and the future; testing.**

production prioritizing Determining which production order should be run first, second, and so on, based on factors such as customer delivery schedule and available sources such as equipment, materials, and people. Prioritizing orders results in a production sequence. See **fabricating.**

production schedule A document that communicates the orders to be produced in a given time period.

productivity A measure of the amount of output in either goods or services per unit of input. The higher the productivity, the higher the output versus input. The recipe for productivity in any company includes a list of ingredients, such as R&D, new technologies, required updated machinery, required automation systems, and modern operating facilities. But the one ingredient that ties the recipe together and makes productivity work is people. See **art and science; color matching; design, innovative; fabricating employment; intelligence; processor certification; quality; training; website; world trade.**

Fabricating productivity depends on factors such as production quantities and product-performance requirements interrelated to cost. These factors include: (1) research and development, (2) new technologies, (3) update on equipment, (4) automated systems, (5) modern facilities, (6) certification, and (7) new plastic materials. Properly trained people are required for efficient fabricating. Optimum use of people requires balancing labor, management, materials science, control engineering, mechanical design, maintenance, and trouble shooting. See **art and science; computer-aided; computerized knowledge-based engineering; entrepreneur; FALLO approach; graphic art; intelligence, emotional; plastic processing; processing, intelligent; processor certification; scientific method; training.** See **computer monitoring information; production data acquisition.**

productivity loss See **medical cost-of-illness study.**

productivity, plant Maximum productivity requires a whole system to work effectively and efficiently and to be responsive to change. The system must evolve with improvement as time passes. The manufacturing conglomeration of individual systems of manufacture, inventory, shop control, purchasing, and accounts payable must be properly integrated.

product liability See **legal matter: product liability law.**

product performance See **injections molding process control; melt-flow analysis; process control.**

product, plastic to See **plastic products, raw material to.**

product release See **medical packaging.**

product safety See **legal matter: Consumer Product Safety Act.**

product scale-up Process improvement for large size runs. For example, scale-up techniques have been used where shear rate is kept constant and Newtonian flow characteristics are used. See **fabrication process.**

product, semifinished Plastic stock material, such as extruded rods and profiles and compression molded blocks, that requires secondary operations such as machining and drilling to produce the finished product. See **operation, secondary; surface finish.**

product shape Both shape geometry and design are heavily process related. For example, the ability to mold ribs may depend on material flow during processing or on the flowability of a plastic reinforced with glass fiber. The ability to produce hollow shapes depends on the ability to use removable cores, including air, fusible or soluble solids, and even sand. Hollow parts can be produced using cores that remain in the part, such as foam inserts. See **design shape; distortion.**

product size See **design product size; dimensional property; heat profile; melt flow; tolerance.**

product surface See **molded-material surface measurement; surface treatment.**

product update Product updates can take the form of a new design or of incremental improvements to an existing product. A new design usually avoids constraints imposed by the incremental approach, but it can be costly in terms of time and resources. If the incremental approach is continued too long, the entire concept runs the risk of becoming obsolete. See **risk.**

product verification See **design verification.**

product via design See **design; Figure 3, Product Design Diagram Incorporating Process Selections.**
product weight test See **test, product weight.**
product workmanship See **legal matter: product liability law.**
professional service See **fabricating outsourcing.**
profile See **die profile; extruder profile; wood-plastic profile.**
profitability study The evaluation of alternative investments to determine the most profitable; the evaluation of the economic success of investments that have been implemented. The earlier a profitability study is carried out in the planning process, the sooner successful alternatives can be implemented. Unnecessary planning work can thus be avoided, and decisions about investments can be made earlier. See **return on investment; sales investment turn; World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**
profit and fabrication See **computer monitoring information; fabricating output.**
profit and loss control See **business bookkeeping.**
profit and technology Keeping up to date on the endless new developments in plastics ensures that the best product design will meet fabricating part performance at the lowest cost. See **FALLO approach; plastic processing.**
profit and time Delay represents a permanently lost profit opportunity: time-is-profit. See **life-cycle analysis; plastics cradle-to-grave.**
profit, benefit-cost See **cost-benefit analysis.**
profit plan The formalization of actions leading to the attainment of profit goals. See **capital-equipment investment; economic efficiency and profitability; FALLO approach.**
program A set of instructions that "tells and documents" exactly what is to be done, how to do it, and when. Also called *computer software.* See **coefficient of scatter; computer software; computerized knowledge-based engineering; process control; test, white-box and black-box.**
programmable controller See **blow molding, extruder, parison programmed-control; computer program; controller; die head, programmed.**
programmable controller die orifice modulation See **blow molding, extruder, parison programmed-control.**
programmable controller reliability See **control-system reliability; reliability.**
programmable-controller safety Safety circuits are used in programmable controllers to protect people and equipment. It is imperative that OEM-supplied circuitry incorporated not be subject to modification or deletion by the end user. See **controller; injection molding, programmed; safety; safety interlock.**
programmable logic See **control actuator; microprocessor control.**
programmable logic controller See **motion-control system.**
programmable sensor See **sensor, intelligent.**
programmed parison See **blow molding, extruder, parison programmed-control.**
programmer Person who writes a program.
project checklist The factors that are to be prioritized by the individual manufacturer or fabricator according to the specific nature of the company's project requirements or expansion: market potential, labor climate, infrastructure, quality of life, business environment, taxes and incentives, sites, financial stability, and regulatory framework. See **business; economic.**
promoter A chemical that is itself a weak catalyst but that greatly increases the activity of a given catalyst. See **accelerator; catalyst.**
promotion See **World of Plastics Reviews: Making Marketing Work.**
property, allowable See **A-basis; B-basis; S-basis; typical basis.**
property difference See **immiscible.**
property, extension A property that depends on how much matter is being considered.
property, intensive A property that does not depend on how much matter is being considered.
property, macroscopic A property that can be directly observed and studied.
property, microscopic A property that cannot be directly observed and studied without the aid of a microscope or other special equipment.
property, specific Material property divided by material density.
property value See **A-basis; B-basis; C-basis; typical basis.**
property versus theoretical See **plastics, theoretical versus actual values of.**
propionate plastic See **cellulose propionate plastic.**
proportional control A control mode in which the output of the controller is proportional to the error.
proportional-integral-derivative See **temperature proportional-integral-derivative control algorithm.**
proportional law See **element, definite proportion law.**
proportional limit The greatest stress that a material is capable of sustaining without deviation from the proportionality of the stress-strain straight line. See **design, Poisson's ratio in; stress, elastic-limit.**
proportional pump See **gear pump.**
proprietary molder See **processor, proprietary.**
propylene tetramer A derivative that is used in plasticizers, surfactants, lubricating oil additives, and polymerization moldifiers. Once manufactured primarily as components of polymer gasoline, they are now valued materials in plastics.
propyleneoxide rubber/elastomer (PPOR) A substance that does not crystallize in its atactic form and has

a low glass transition temperature of −72°C (−98°F). Its copolymer with allylglycidylether (AGE) allows conventional vulcanization. It has excellent dynamic properties (resilience, etc.). See **glass transition temperature; vulcanization.**

propylene plastic A plastic that is based on polymers of polypropylene or copolymerizes propylene with other polymers with the propylene being the greatest amount by mass.

prostheses Artificial body parts, such as fingers, wrist joints, elbows, ankles, hips, and knees. Plastics that are used include UHMWPE and other polyethylene compounds, silicones, reinforced carbon-polysulfone, and PUR.

protection See **design protection; rail track protection; safety; screw-wear protection; surface coating.**

protein **1.** Any of the naturally occurring extremely complex combinations of amino acids that contain the elements of carbon, hydrogen, nitrogen, or oxygen. **2.** The total nitrogenous material in plant or animal substances.

proteinaceous See **adhesive, proteinaceous.**

protein, conjugated A protein that contains other groups in addition to amino acids.

protocol, communication See **communication protocol; test, white-box and black-box.**

protocol, Kyoto An international agreement concerning the environment. In addition to the curbs put on the greenhouse gas emissions starting in 2008, fluorochemicals were included in the Kyoto protocol. Increased usage of hydrofluorocarbons is now possible, but at the expense of other gases. Under the Kyoto protocol, it appears that energy efficiency and environmental responsibility will permanently affect product design, including that of polyurethane components. See **polychlorofluorocarbon.**

protocol, Montreal An international agreement concerning ozone-deletion. As the 2003 deadline nears for phasing out the use of ozone-depleting hydrochlorofluorocarbons, their users, such as polyurethane foamers, continue their target for replacements. Liquid hydrofluorocarbons have the potential to replace the HCFC blowing agent that is used in rigid insulation PUR foams in the United States. Developments in additives and chemical structural changes in the basic polymers are occurring to meet the ozone-ODP (ozone depletion potential). See **environmentally friendly additive; foam and blowing agent; ozone; polychlorofluorocarbon.**

proton A fundamental unit of matter having a positive charge. Protons are constituents of all atomic nuclei, their number in each nucleus being the atomic number of the element in the periodic table. A proton is basically a subatomic particle having a mass of about 1,840 times that of an electron. See **atom; mass; nucleus.**

proton, Bronsted-Lowry See **Bronsted-Lowry acid; Bronsted-Lowry base.**

prototype A three-dimensional model suitable for use in the preliminary evaluation of form, design, performance, and material processing of molds, products, and dies. See **computer modeling; dimensioning and tolerancing, geometric; machine, coordinate-measuring; modeling.**

prototype, rapid Three-dimensional parts (to date principally for injection molding) that have been created by computer-controlled laser beams that produce layers of the final simple to complex shaped parts. Models can be made of plastics (nylon, etc.) or metals (steel, hard alloys, copper-based alloys, powdered metals). With powder metal molds, they can be used as inserts in a mold ready to produce prototype parts. When properly used this automatic/fast system can accelerate product development, improve product quality, and time to the market. See **computer-aided design; laser-sintering, selective.**

prototyping modeling mold A simplified mold construction often machined from a light metal casting alloy or epoxy plastic to obtain information for the final mold or part design.

prototyping modeling mold, rapid Different computer-aided design and advanced machining techniques provide fast manufacture of precision molds. An example is MIT's three-dimensional printing, in which a three-dimensional metal mold (die, etc.) is created layer by layer using powdered metal (300- or 400-series stainless steel, tool steel, bronze, nickel alloys, titanium, etc.). Each layer is inkjet-printed with a plastic binder. The print head generates and deposits micron-sized droplets of a proprietary water-based plastic that binds the powder together. Once the lay-up is completed, the part is removed and placed in a sintering oven. It goes through three cycles where plastic is burned off, metal powder is sintered together, and the part is solidified by infiltrating with another material to fill the voids such as lower melting point metal or a plastic (epoxy, etc.). Total time is 50 h. The shape is accurate within 0.005 in., plus 0.002 in./in. (0.0127 cm, plus 0.0051 cm), and may be acceptable for prototyping. The tool can be machined to tighter tolerances and polishing. This process permits creation of any type of internal voids, such as cooling lines that conform to the part shape. See **computer-aided design; machining; mold; surface finish.**

prototyping modeling, stereolithography A three-dimensional rapid process that produces simple to very complex part models in plastic. This process uses a moving laser beam, directed by a computer, to prepare the model. See **laser sintering, selective.**

pseudo-elastic method, designing See **designing with the pseudoelastic method.**

pseudoplastic A material in which viscosity decreases with rate of shear, but the material deforms as soon as shearing stress is applied. This class of materials has the greatest industrial applications since all high polymers and polymer melt follow this behavior. See **dilatant; melt**

shear rate; orientation and mechanical property; rheology; viscoelasticity.

pseudoplasticity See **viscosity, non-Newtonian flow.**

psi Pounds per square inch.

psychological acceptance See **test, organoleptic.**

psychrometer See **temperature, wet-bulb.**

P-T diagram A two-dimensional graphic representation of the phase relationships in a system of any order by means of the pressure and temperature variables.

P-T-X diagram A three-dimensional graphic representation of the phase relationships in a binary system by means of the pressure, temperature, and concentration variables.

publication See **Appendix F, Trade Magazines and Publications.**

public opinion and plastic See **environment and public opinion; risk, acceptable.**

pucker See **prepreg.**

puckering See **extruder film cooling roll versus quench-tank.**

puller A device that is used to move, for example, the extrudate from an extruder die at a controlled rate. The usual form is either a pair of rollers or two belts in opposition with the extrudate "pinched" between.

pulling screw from plasticator See **extruder screw pulling; injection-molding screw pulling; screw removal.**

pulp See **cellulose; paper; wood pulp.**

Pulsar mixer See **screw mixing, Pulsar.**

pulse cooling See **injection-molding melt-pulse cooling.**

pultrusion See **reinforced-plastic pultrusion.**

pulverizing See **calcining; material pulverizing.**

pumice An abrasive powder made from highly porous igneous rock. It is used as an abrasive and filler. See **abrasive; ashing; surface pumicing; tumbling, wet.**

pump, positive displacement A pump that displaces material at a constant rate over a wide range of conditions with no internal losses. See **gear pump.**

pump, variable displacement A hydraulic pump whose output can be varied using electrical controls.

punch **1.** See **cutter, die; machining and punching.** **2.** A part of a die or compacting tool set that is used to transmit pressure to the material in a die cavity.

punch, floating See **press, floating punch.**

punching device A method for measuring the resistance and strength of a material subjected to puncture with the action involving tear and stiffness. See **burst strength; test, burst Mullen; test, tear-resistance.**

purchase order (PO) A document describing what has been ordered by the customer. All requirements need to be clearly defined on the PO; there should be no verbal (unwritten) requirements. See **fabricating, asynchronous; production order quantity.**

purchase order, blanket (BPO) A purchase order placed with a supplier for materials and services over a set time period. The supplier then releases material and services as required or as specified. See **backlog.**

purchase order hold An order on which administration and production processing is suspended usually because of a customer request, depleted material inventory, or equipment failure.

purchasing decision See **technology assessment.**

purging The extracting of volatile components from a plastic. See **devolatilization; venting purifier.** At the end of a production run the plasticator has to be cleared of all plastic from the barrel or screw to eliminate barrel or screw corrosion or contamination. It is also required when a change of material occurs. This action consumes substantial nonproductive amounts of plastics, labor, and machine time. It is sometimes necessary to run hundreds of pounds of plastic to clean out the last traces of a dark color before changing to a lighter one; if a choice exists, the light color should be processed first. Sometimes the screw must be pulled for a thorough cleaning.

There are a few generally accepted rules on purging agents to use and how to purge. The following tips should be considered: (1) try to follow less viscous with more viscous plastics; (2) try to follow a lighter color with a darker color plastic; (3) maintain equipment by using preventative maintenance; (4) keep the materials-handling equipment clean; and (5) use an intermediate plastic to bridge the temperature gap, such as that encountered in going from acetal to nylon.

Ground or cracked cast acrylic and PE-based (typically bottle-grade HDPE) materials generally are the main purging agents. Others are used for certain plastics and machines. Cast acrylic, which does not melt completely, is suitable for virtually any plastic. PE-based compounds containing abrasive and release agents have been used to purge the "softer" plastics such as other olefins, styrenes, and certain PVCs. These purging agents function by mechanically pushing and scouring residue out of the extruders.

purification The removal of extraneous materials (impurities) from a substance or mixture can be accomplished by one or more separation techniques. A pure substance is one in which no impurities can be detected by any experimental procedure. Though absolute purity is impossible to attain, a number of standard procedures exist for approaching it to the extent of 1 ppm or even less. See **carbon black, animal; devolatilization; material impurity; venting purifier.**

putty The historical putty is a mixture of whiting (chalk) with 12 to 18wt% of linseed oil, with or without white lead or other pigments. New putties have been formulated. There are plastic putties with a range of different capabilities using such plastics as diallyl phthalates, silicones, vinyls, polyurethanes, and thermoset polyesters. The plastic types provide much more stability, longer life, and permanent colors. It is used in sealants, window glass settings, and caulking agents.

putty, body A specialized putty for the repair of auto body surfaces and boats. It is usually a mixture of thermoset polyester plastics with fillers such as talc. See **caulking compound; polyester plastic, thermoset; talc.**

putty, bouncing A boron-containing silicone that has the surprising property of rebounding when dropped. Compounds are available that bounce under a free fall close to the height. It is perhaps best known as a novelty item sold commercially as Crazy Putty, Nutty Putty, or Silly Putty.

pyrolysis **1.** The technology of decomposing organic materials at high temperatures, such as 1,000 to 2,000°F (540 to 1,080°C). See **ablative plastic; incineration; waste. 2.** In waste-handling combustion facilities, decomposition caused by heat in an oxygen-deficient atmosphere. Running at 500 to 900°C in an oxygen-free atmosphere, it produces gaseous hydrocarbons, ammonia, and hydrogen chloride (up to 50%), synthetic crude (25 to 40%), and solids residue. See **recycling, chemical. 3.** The thermal process by which plastic precursor fiber materials are chemically changed into carbon or graphite fibers by the action of extremely high temperature. See **allophanate; decomposition; endothermic; fiber, carbon; fiber, graphite; graphitization; mesophase; pitch; polyacrylonitrile plastic; precursor.**

pyrolysis, vacuum See **cleaning, vacuum-pyrolysis.**

pyrolyzation A chemical change brought about by the action of heat, such as occurs in carbonization.

pyrometer An electrical thermometer for measuring and recording temperatures. A pyrometer with a surface contact probe is essential in many fabricating lines and troubleshooting. The contact probe can be used to check for heater burnout, heat flow, and temperature balance. It can check melt thermocouple accuracy and also check the actual melt temperature as it exits the die. For example, die exit temperature is often much higher than the melt-probe temperature, which is usually indicated near the screw discharge and is influenced by adapter metal temperature. See **radiation, pyrometer; temperature measurement; temperature sensor; thermocouple; troubleshooting.**

pyrophoric material Any liquid or solid that will ignite spontaneously in air at about 54°C (130°F). See **combustion, autoignition point; ignition.**

pyrrone plastic Polyimidazo-pyrrolones that are synthesized from dianhydrides and tetramines. This plastic is soluble only in sulfuric acid and resistant to temperatures up to 600°C (1,112°F). See **temperature properties of plastics.**

Q

qualification test A test that is conducted by a procuring plant to determine conformance of materials to the requirements of a specification, worksheet, or qualified products list. See **design verification; ISO-9000 certification; specification.**

qualified products list (QPL) A list of commercial products that have been pretested and found to meet the requirements of a specification.

qualitative analysis An analysis by analytical methods in which some or all of the components of a product or sample are identified irrespective of their amounts. See **quantitative analysis.**

qualitative chemical analysis An analysis to determine the chemical nature of the constituents of a material, irrespective of their amounts. See **chemical analysis; test, chemical property.**

quality **1.** A manufacturing term reflecting variation from a norm when the norm represents the absolute specifications such as weight, volume, and appearance of the part being fabricated. **2.** An aspect, attribute, characteristic, or fundamental dimension of practical experience that involves variation in kind rather than degree. **3.** The composite of those characteristics that differentiate among individual units of a product and have significance in determining the degree of acceptability of that unit by the user. See **reliability; computers and statistics; statistical benefit.**

quality acceptance number See **quality level, acceptable.**

quality analysis See **cost-utility analysis.**

quality and control Quality in products starts with a good design concept, a good problem statement, an identification of requirements and objectives, understanding of the end user and alloys for simplifying selection of tests, and a reasonable schedule that includes all company functions involved. See **computer-aided quality control; design; FALLO approach; plastic material selection; statistical normal curve.**

quality and training See **education; training and quality.**

quality assurance (QA) The planned and systematic actions that are necessary to ensure that a processing facility or product will perform satisfactorily in service. It includes quality control, quality evaluation, and design assurance. A good QA program is a coordinated system, not a sequence of separate and distinct steps. It is an independent audit or evaluation of the quality function. It can be compared to the finance function. Its major elements are management of QA, product and process quality evaluation and control, quality training and personnel development, product quality and reliability development, product and process quality planning, supplier quality studies, quality information feedback, quality measurement equipment, and field quality evaluation and control. See **ISO-9000 certification; sterilization quality assurance; sterilization radiation.**

quality assurance test A test in a program that is conducted to determine the quality level.

quality auditing An audit evaluates the existence and adequacy of the quality assurance program and ensures that the manufacturer's operations are in compliance with it.

quality control (QC) Quality control requires consistent materials that can be used with a minimum of uncertainty. This involves inspection and testing of raw materials to products. Plant QC is as important to the end result as is selecting the best processing conditions with the correct grade of plastic, in terms of both properties and appearance. After the correct plastic has been chosen, its blending, reprocessing, and storage stages of operation need to be frequently or continuously updated. The processor should set up specific measurements of quality to prevent substandard products from reaching the customer. QC involve those quality-assurance actions that provide a means to control, measure, and establish requirements of the characteristics of plastic materials, processes, and products.

From a practical aspect, the expression *quality control* refers to a product that fulfills customer's expectations. These expectations or standards of performance are based on the intended use and selling price of the product. Control is the process of regulating or directing an activity to verify its conformance to a standard or specification and to take corrective action if required. Therefore, QC is the regulatory process for those activities that measure a product's performance, compare that performance with established standards or specifications, and pursue corrective action regardless of where those activities occur.

There are various methods for applying QC on-line. For example, measurement of the infrared spectra of plastic melts provides process monitoring and control in the manufacturing process. Precise information on quality can be obtained rapidly. Furthermore, it is also possible to make measurements on unstable intermediates of importance. Although spectroscopy on melts is considerably different from that on solid materials, this does not limit the information content. IR has fór many years been an important aid to investigating the chemical and physical properties of molecules. It gives qualitative and quantitative information on chemical constituents, functional groups, and impurities. It is used in studying low-molecular-weight compounds and in characterizing plastics. It is a highly informative method of applying testing. See **infrared; in-**

spection; testing. See **accuracy; inspection; inspection, vision-system; material handling; material received, checking; part handling; probability; process control; repeatability; risk, acceptable; sampling; statistical process control; statistical quality control; storage; testing; testing and quality control; test method conformance; viscoelasticity, linear; warehousing; zero defect.**

quality control, acceptable See **sampling acceptable quality level.**

quality control, image See **computer image-processor; inspection; inspection, vision-system.**

quality control, kinetic See **viscoelasticity, linear.**

quality-control manual A document that is usually set up in a computer's software program and that states the details of the plant's quality objectives and how they will be implemented, documented, and followed.

quality control monitoring See **extruder-web tension control, slipping and learning.**

quality control online infrared measurement See **infrared spectroscopy; quality control.**

quality control stress measurement See **test, nondestructive photoelastic stress-analysis.**

quality control variable There are three phases in the evolution of most QC systems; (1) defect detection, where an army of inspectors tries to identify defects; (2) defect prevention, where the process is monitored, statistical methods are used to control process variation, and adjustments to the process are made before defects are produced; and (3) total quality control, where quality is extended throughout all functions and management integrates and leads the various functions toward quality and a customer-first orientation. The defect-detection approach to quality control does nothing to improve the process and is not very good at sorting good from bad. Also, sampling plans developed to support an acceptable quality level of 5%, for example, mean that a company is content to deliver 5% defects.

quality control, volatile See **prepreg volatile content; volatile content.**

quality cost, direct A cost that can be separated into categories, such as prevention, appraisal, internal failure, and external failure. Each of these four categories is made up of a number of subcategories that in turn simplify the collection, reporting, and analysis of the information. See **cost.**

quality cost overview Quality products must contribute to company profits, and profit analysis is as important as design, production, control, and packaging the products. Quality costs provide (1) a means of assessing the overall effectiveness of the quality program, (2) a means of establishing programs to meet overall needs, (3) a method for determining problem areas and action priorities, (4) a technique for determining the optimum amount of effort needed by the various quality activities, and (5) information for pricing products or bidding on jobs. Producing products that have a high level of quality is not enough. The cost of achieving that quality must be carefully managed so that the long-range effect of quality costs on the company's profits is a desirable one. This is the true measure of the quality effort. See **cleanroom; cost; economic and product quality; economic efficiency and profitability; engineered, re-.**

quality factor, performance The ratio of elastic modulus to loss modulus (measured in tension, compression, flexural, or shear). This effect is a nondimensional term. See **modulus of elasticity.**

quality indicator, image (IQI) In industrial radiology, a device or combination of devices whose demonstrated image or images provide visual or quantitative data to determine radiological quality and sensitivity. It is not intended for use in judging size or establishing acceptance limits of discontinuities. Also called *penetrameter.* See **optical density; optical distortion value.**

quality level, acceptable (AQL) The maximum allowable number of defective parts for a given acceptable quality and lot sample. AQL is a quality of product, expressed as a percent defective, such that a lot having this percent defective will have a probability of rejection by the customer. An ideal sampling and inspection plan would accept all lots of better quality and reject all lots of lower quality. Any practical plan can approach this ideal. AQL is the process average at which the risk of rejection is called the *producer's risk.* See **sampling acceptable quality level.**

quality management, environment See **ISO-14000 certification.**

quality management, total (TQM) A principle of manufacturing associated with the adage "do it right the first time." This term is not associated with any product but reflects a philosophy and its implementation. See **design, medical-device; ISO-9004 certification.**

quality of life (QOL) The social, physical, emotional, psychological, and general well-being of people. Interviews and questionnaires typically measure it. See **productivity.**

quality optimization goal Quality is always a compromise between many different requirements. It provides not only the goal that is to be attained by the optimization but many individual partial goals. These include product dimensional stability during fabrication, reduction of warpage, improving surface finish, and increasing output rate. However, with improvements potential problems or performance loss in other areas can occur. The target is to obtain the proper or ideal compromise. Also called *quality of conformance.* See **control; design; design, optimized; population confidence level; process control; risk, acceptable, testing.**

quality, product See **economic and product quality.**

quality system QS-9000 The standard QS-9000 is an augmentation of the ISO-9000 standard that was created for the automotive industry. See **ISO-9000 certification.**

quality-system regulation (QSR) The new term for good manufacturing practice (GMP) and process validation (PV). It is important for the medical-device industry (which uses an extensive amount of plastics) and also in other product industries that follow strict processing procedures that meet zero defects. The Food and Drug Administration defined GMP and PV as a documented program providing a high degree of assurance that a specific process will consistently produce a product meeting its predetermined specifications and quality attributes. Elements of validation are product specification, processing equipment, and process revalidation and documentation. The GMP regulation became effective in 1978. As of October 7, 1996, GMP was revised to incorporate many changes and renamed *quality-system regulation*. The GMP focused almost exclusively on production practices that required very detailed manufacturing procedures and extremely detailed documentation with QSR, major new requirements are in the areas of design, management responsibility, purchasing, and servicing. It encompasses quality system requirements that apply to the entire life cycle of a device. See **cleanroom; control, change; design, biomedical-product; design control and quality-system regulation; design, medical-product; inspection; legal matter; plastic product failure; specification; sterile.**

quantitative analysis A measure that determines the amount of one or more components of a product or sample. See **qualitative analysis; statistic.**

quantity See **percentage point; production order quantity.**

quantity lower range value The lowest quantity that a device is adjusted to measure.

quartz Ground quartz is used as an additive or filler. See **fiber, quartz.**

quartz heater See **thermoforming heater, tubular quartz.**

quartz sand See **fluid-bed process.**

quasi-isotropic property See **directional property, isotropic.**

quench The process of sudden cooling or shock-cooling products in water or air from a molten state as soon as they are removed from the process (molded part, extruded pipe, etc.) and for a specific time period. To control time of immersion or exposure, various techniques are used. For example, continuous, open, basketlike filament (wire, etc.), woven-type containers move parts through agitated, temperature-controlled water rather than just dropping them into a tank and periodically collecting them. However, products such as extruded or calendered film are cooled by passing through a quench water bath tank or air-forming jigs. See **annealing; melt.**

quench aging Aging that is induced by rapid cooling after annealing or heat treatment. See **aging.**

quench annealing See **annealing.**

quench bath The cooling medium, usually water, that is used to quench molten thermoplastics to the solid state.

quer-wave A dispersive surface wave with one horizontal component. It is generally normal to the direction of propagation velocity with increase in frequency. Also called *love wave*.

quick burst strength See **burst strength.**

quicklime A calcined limestone whose major constituents are calcium oxide or calcium oxide in association with magnesium oxide. It is capable of slaking with water. See **lime.**

quick setting ink See **printing ink.**

quotation See **cost; legal matter: quotation.**

R

rad The quantity of ionizing radiation that results in the absorption of 100 ergs of energy per gram of irradiated material. See **energy absorption, megarad; ionization.**

radar doppler effect See **electronic doppler effect.**

radian (rad) The SI unit for a plane angle. Use of degree and its decimal submultiple is permissible when the radian is not a convenient unit. One degree (°) equals rad × 0.017533 or 1° equals ($\pi/180$) rad.

radiation The process of emitting radiant energy in the form of waves or particles. It is the combined processes of emission, transmission, and absorption of radiant energy. See **cobalt-60; curie; energy; gamma radiation; heat; heater; irradiation; printing ink, radiation; resinography; sterilization, radiation; ultraviolet radiation.**

radiation, absorbed dose The amount of energy imparted by ionizing radiation per unit mass of irradiated matter.

radiation activation The process of inducing radioactivity in a material by bombardment with neutrons or other types of radiation. See **neutron.**

radiation blackbody In radiation physics, a theoretical object that absorbs all radiant energy falling on it and emits it in a form of thermal radiation.

radiation coating See **polymerization, photo-.**

radiation cure See **extruder wire and cable process.**

radiation damage A structural defect arising from exposure to radiation. See **radiation-induced reaction.**

radiation depth dose The variation of absorbed dose with distance from the incident surface of a material exposed to radiation. Depth dose profiles give information about the distribution of absorbed energy in a specific material.

radiation, diffraction **1.** A modification that radiation undergoes, as in passing by the edge of opaque bodies or through narrow slits in which the rays appear to be deflected. **2.** The coherent scattering of x-radiation by the atoms of a crystal, which results in beams having characteristic directions. See **electron scattering.**

radiation dome See **radome.**

radiation dose The amount of ionizing radiation energy received or absorbed by the material during exposure. Also called *radiation dosage* or *ionization radiation dose.* See **ionization.**

radiation dose equivalent The sievert (Sv) is the dose equivalent when the absorbed dose of ionizing radiation is multiplied by the dimensionless factors Q (quality factor) and N (product of any other multiplying factors). As stipulated by the International Commission on Radiological Protection, this is 1 joule per kilogram (J/kg).

radiation dosimeter An instrument for measuring radiation-induced signals that can be related to absorbed dose, or energy deposited, by radiation in materials. Calibration is in terms of the appropriate quantities and units. Also called *dose meter.*

radiation dosimeter, primary-standard A system that measures energy deposition directly without the need for conversion factors for interpretation of the radiation absorption process. Examples of such systems are calorimeters and dosimeters. See **calorimeter.**

radiation dosimeter, secondary-standard A system that measures energy deposition indirectly. It requires conversion factors to account for such considerations as geometry, dose rate, relative stopping power, incident energy spectrum, or other effects in order to interpret the response system. Thus, it requires calibration against a primary dosimeter system or by means of a standard radiation source.

radiation dosimeter, solid-phase chemical An apparatus that measures radioactivity by using plastic, dyed plastic, or glass with an optical density, usually in the visible range, that changes when exposed to ionizing radiation. Examples include dyed PMMA, undyed PVC, dyed PA, and dyed polychlorostyrene. This method is also considered to be a secondary-standard dosimeter system. See **ionization.**

radiation, electromagnetic See **electromagnetic radiation; extruder wire and cable cross-linking radiation without peroxide; fiber optic; infrared spectroscopy.**

radiation, electronic See **electromagnetic interference.**

radiation fallout The deposition on earth of the radioactive particles resulting from a nuclear explosion. Some plastics that have damage resistance to nuclear fallout. See **radiation-resistant plastic.**

radiation-induced reaction A reaction that is induced in monomers and plastics by ionizing radiation and by certain aspects of the photochemistry of plastics. Reactions include radiation-induced polymerization, radiolysis of plastics, and radiation graft copolymerization. The transformations occurring include chain scissions, cross-linking, and changes in saturation. Some common plastics resist radiation damage. The most stable contain aromatic benzene groups, such as polystyrene and phenolic plastics. See **aromatic; chemical benzene ring; chemical reaction; degradation; degradation, scission; grafting; ionization; polymerization, photo-; radiation damage; radiation-resistant plastic.**

radiation, monochromatic Radiation at a single wavelength and, by extension, radiation of a very small range of frequencies or wavelengths. See **candela; wavelength.**

radiation, photon The unit (quantum) of electromagnetic radiation. It is a discrete concentration of energy that seems to have no rest mass and moves at the speed of light. Basically, it is a particle of light. Just as matter is composed of atoms, light is composed of photons (quanta). Light waves, gamma rays, and x-rays consist of photons. See **polymerization, photo.**

radiation polymerization A polymerization reaction that is initiated by exposure to radiation such as gamma rays rather than by means of chemical catalysts. See **catalyst; polymerization; sterilization, radiation.**

radiation pyrometer An instrument for determining temperatures by measuring the radiance (radiant energy per unit area) from an object. See **pyrometer; temperature measurement; thermocouple.**

radiation-resistant plastic Ionizing radiation can significantly alter the molecular structure and macroscopic properties of plastics. Plastics exhibit a wide range of radiation stabilities. Radiation resistance is strongly influenced by the basic macromolecular structure, the presence of certain types of additives, and particular environmental exposure conditions. See **ionization; molecular structure; radiation fallout; radiation-induced reaction; sterilization radiation.**

radiation, tent-value-layer (TVL) The thickness of the layer of a specified substance that, when introduced into the path of a given narrow beam of radiation, reduces the intensity of this radiation by a factor of 10.

radical Fragment of a molecule that contains an unpaired electron. With two or more atoms present in a compound, some of them occasionally group themselves and behave as a unit in a chemical reaction.

radioactive Spontaneous nuclear disintegration with emission of corpuscular or electromagnetic radiation.

radioactive beta particle A charged particle from a radioactive atomic nucleus either natural or synthetic. It carries a single charge. If it is negative, the particle is identical with an electron; if positive, it is a positron. Beta rays cause skin burns. See **electron; positron.**

radioactive decontamination The removal of radioactivity in equipment and personnel areas. See **hazard.**

radio-frequency interference See **electromagnetic interference; plastic, electrically conductive.**

radio-frequency preheating Preheating raw materials to facilitate the fabricating operation or reduce fabricating time. The frequencies most commonly used are from 10 to 100 mc/s. See **electrical radiation.**

radiographic contrast The difference in density between an image and its immediate surroundings on a radiograph.

radiograph imaging See **digital imaging.**

radiographic inspection The use of x-rays or nuclear radiation to detect discontinuities in material and to present their image on a recording medium. See **inspection.**

radiography See **test, nondestructive radiography.**

radiography, cine- The production of a series of radiographs that can be viewed rapidly in sequence, thus creating an illusion of continuity.

radioisotope An isotopic form of an element (either natural or artificial) that exhibits radioactivity. It is used as a tracer when melting plastics (through extruder, injection, etc.), measuring thickness (films, profiles, molded wall, etc.), and initiating polymerization reactions. See **isotope.**

radiolysis of plastic See **radiation-induced reaction.**

radiometer An instrument for measuring radiation in energy or power units.

radionuclide decaying activity The becquerel (Bq) is the activity of a radionuclide decaying at the rate of one spontaneous nuclear transition per second.

radius of gyration The average distance of the mass in a molecule from the center of its mass. See **molecular mass.**

radome A cover for a microwave antenna that protects the antenna from the environment on the ground, underwater, and in the air (aircraft nose cone, etc.). The dome is basically transparent to electromagnetic radiation and structurally strong. Various materials have been used, such as wood or rubber-coated air-supported fabric. The most popular is the use of glass-fiber thermoset polyester reinforced plastics. The shape of the dome, which is usually spherical, is designed not to interfere with the radiation. Also called *radiation dome*. See **electronic doppler effect; polyphosphazene plastic; rain; reinforced plastic; test, coin impact.**

rail-car contamination Transportation (particularly rail cars) and handling (particularly unloading) offer numerous possibilities for material contamination. See **contamination; material handling; storage.**

rail car, Glasshopper A filament wound tank made of glass-fiber thermoset polyester reinforced plastic. It was lighter than steel cars and passed all operating performance tests, but the price was not lower. Cargill Inc., Southern Pacific, and ACF Industries were involved with the Glasshopper in 1973. See **filament winding; material handling; reinforced plastic.**

rail car, SCRIMP An insulated reinforced plastic rail car (1995) that weighs 15,500 lb or 50% less than a steel box car and at the same time offers a bigger payload (200,000 lb) and cubic capacity (6,100 ft^3). Its shell is made from two plastic parts. The floor, end walls, and sidewalls are made in one shot using 13,000 lb of reinforced plastic. See **material handling; reinforced-plastic SCRIMP process.**

rail car unloading See **material handling, automatic.**

railroad freight car fee See **cost, demurrage; tare.**

rail-track protection One factor in railroad safety is weed control since weed roots can affect the structure and configuration of the rail bed. A wide-tie rail track that uses concrete ties with PVC profiles in between the narrow gaps of the ties eliminates the growth of weeds. This construction is weather resistant, durable, flexible, and resistant to abrasion and has good stability in extreme temperatures.

rain Raindrops rarely exceed 6 mm in diameter because they become unstable when larger than this size and break up during their fall. Raindrops can be small destructive "bullets" when they strike high-speed aircraft. They can erode paint coatings, plastic parts (radomes, etc.), and even nonplastics (aluminum, magnesium, etc.). Erosion by rain on the exterior of high-speed aircraft (400 mph) was observed during 1941 on aluminum and the reinforced plastic radome (particularly the eagle wing on the B-29 bomber) over the Pacific Ocean. A protective measure, still being used on commercial aircraft, is an adhesively applied 5-mil coating of an elastomeric material (neoprene plastic) that literally caused the raindrops to bounce off the reinforced plastic. There was about 1% per mil thickness of radar transmission loss. See **acetal plastic; erosion; radome; reinforced plastic; wear; weather condition, normal.**

rain forest See **canopy, rain-forest.**

ram See **extruder ram; extruder wire and cable, ram; injection molding machine, ram; plunger.**

Raman spectroscopy See **spectroscopy, Raman.**

ram booster A ram that is usually hydraulically operated and used as an auxiliary to the main ram of a machine, such as a molding press. See **pressure booster.**

ram extrusion See **extruder wire and cable, ram.**

ram force The total load applied, normally expressed in tons, by a ram that is numerically equal to the product of the line pressure and the cross-sectional area of the ram. This action is used in different processing systems, such as the compression-molding machine hydraulic ram action, the injection-molding screw that is used as a ram when melt is to be pushed into a mold cavity, and extruding by ram action (with or without a screw) to move plastics that cannot be melted in screws.

ramie See **fiber, ramie.**

ram injection molding See **screw torpedo; spreader.**

ram input An input with a constant rate of change other than zero.

ramping A gradual programmed increase or decrease in temperature or pressure to control the cure or cooling of plastic parts, such as reinforced plastics. See **cure; reinforced plastic.**

ram stuffer See **hopper stuffer.**

ram travel The distance that an injection ram moves to fill a mold during injection molding (with a screw or plunger ram system), extrusion ram, or transfer molding. See **extruder, ram; injection-molding machine, ram; transfer molding.**

randomization See **error randomization.**

range **1.** The absolute value of the algebraic difference between the highest and the lowest values in a set of data. See **algebra.** **2.** The range between the limits within which a quantity is measured. It is expressed by stating the lower and upper range values.

Rankin scale (R) A temperature scale that uses Fahrenheit (F) degrees but makes the zero degree signify absolute zero (−459.72°F). To obtain an approximate R, add 460 to °F. See **temperature.**

Raoult's law The vapor pressure of a substance in equilibrium with a solution containing the substance is equal to the product of the mole fraction of the substance in the solution and the vapor pressure of the pure substance at the temperature of the solution. This law is not applicable to most solutions but is often approximately applicable to a mixture of closely similar substances, particularly the substance present in high concentration. See **drying; equilibrium vapor pressure; mole; solution, ideal; vapor pressure.**

rapid loading See **impact strength.**

rapid marking See **laser marking.**

rapid tooling/rapid prototyping See **prototype, rapid.**

rasp See **waste rasp.**

rate-determining step The slowest step in the sequence of steps leading to the formation of products.

rate law An expression relating the rate of a reaction to the rate constant and the concentrations of the reactants raised to the appropriate powers.

rate term See **temperature controller rate term.**

ratio The quantities of one substance to another substance on a weight or volume basis. See **extruder drawdown; modulus; screw length-to-diameter ratio.**

raw material See **plastic products, raw material to.**

rayon See **fiber, rayon.**

reactant See **chemical reactant.**

reaction See **chemical reaction.**

reaction foam molding See **foam and process; reaction injection molding.**

reaction injection molding (RIM) A process for molding polyurethanes. Also used for epoxies, nylons, and other liquid chemical systems. Unlike liquid casting, the two liquid components, polyols and isocyanates, are mixed in a chamber at relatively low temperatures of 75 to 140°F (24 to 60°C) before being injected into a closed mold. On mixing, an exothermic reaction occurs that requires less energy than other injection molding systems. The main RIM type systems using PURs are rigid structural foam, low-modulus elastomers, and high-modulus elastomers.

The plastics polymerize after entering a mold. Mixing two or more components (additives, fillers, and reinforcements) in the proper chemical ratio is accomplished by a high-pressure impingement-type mixing head. This mix is directed into the mold cavity at low pressure, where it chemically reacts to form a plastic. The components are mixed together at a given ratio and then directed or basically poured into a mold under controlled temperature, pressure, and rate of flow. They polymerize and cure in the mold to form a molded part; the mold cavity could include reinforcement such as a woven or nonwoven fabric. The majority of RIM systems are based on polyurethanes or polyurethane-polyurea hybrids. They can be prepared so that a solid or rigid integral skin is formed on the flexible foam moldings. Solid moldings are elastomeric with high or low modulus. Also called *liquid injection molding, reactive injection molding,* or *LIM.* See **exotherm; foam, structural; injection molding, liquid; modulus; polymer, reactive; reinforcement.**

reaction-injection molding day tank A tank that contains the chemical components and that is usually mounted on or near the machine. Tanks maintain the components at process temperature and feed the machine for production.

reaction injection molding degassing Applying a vacuum to the day tank to remove dissolved gases and entrapped gas bubbles.

reaction injection molding demold time The time from when the reactive materials have been mixed and injected into the mold to a point at which sufficient cure is achieved. This time period enables removal from the mold without damage.

reaction injection molding free rise The unrestricted rise of a foam.

reaction injection molding green strength See **plastic green strength; tensile green strength.**

reaction injection molding, impingement mixing Forcing together of two disparate liquid streams under high pressure. It is used for mixing of polyol and isocyanate in RIM. See **mixing, impingement.**

reaction injection molding lockout See **safety, machine-lockout.**

reaction injection molding machine daylight See **clamping daylight opening.**

reaction injection molding mold See **mold.**

reaction injection molding, one-shot See **foamed, one-shot system.**

reaction injection molding operator's sequence See **operation, automatic; operation, manual; operation, semiautomatic.**

reaction injection molding peak rise point The highest rise a foam may achieve prior to the occurrence of cell rupturing and thereafter settling.

reaction injection molding, prepolymer See **foamed, prepolymer.**

reaction injection molding, pressure See **pressure, locking.**

reaction injection molding process control safety See **programmable controller safety.**

reaction injection molding, reinforced See **reinforced plastic reaction-injection molding.**

reaction injection molding rise time See **foamed rise time.**

reaction-injection molding self-cleaning The ability of a mixing head to mechanically expel all mixed materials from the mixing head at the end of each shot. Without self-cleaning, the next shot may not occur or may be contaminated, producing an unacceptable part.

reaction injection molding short shot See **short.**

reaction injection molding, soluble core See **eutectic mixture; soluble-core molding.**

reaction injection molding, structural A RIM product with structural strength that usually contains reinforcing fibers. It has some similarity to resin transfer molding (RTM), but its plastic chemistry is different. See **reinforced-plastic resin transfer molding.**

reaction injection molding tack free time See **tack-free time.**

reaction injection molding temperature stratification A condition encountered in tanks when they do not have sufficient agitation to maintain a homogeneous state.

reaction mechanism The sequence of elementary steps that leads to product formation.

reaction order The power (or exponent) to which a concentration of a reactant needs to be raised in the rate law expression.

reaction quotient A number that is equal to the ratio of product concentration to reactant concentration, each raised to the power of its stoichiometric coefficient at some point other than equivalent. See **chemical reaction; stoichiometry.**

reaction rate A measure of how rapid a reaction occurs. It is the change of the reactant or product concentration divided by the time required for the change to occur.

reaction, redox A reaction in which there is either a transfer of electrons or a change in the oxidation numbers taking part in the reaction. See **redox.**

reaction spinning See **fiber processing, spinning, reaction.**

reaction, termolecular See **molecular, ter-.**

reaction, thermonuclear See **thermonuclear reaction.**

reaction, unimolecular See **molecular, reaction, uni-.**

reaction, viscosity See **processing, reaction viscosity.**

reaction versus temperature rate See **chemical reaction versus temperature rate.**

reactive diluent A formulation or compound containing one or more diluents that functions mainly to reduce the viscosity of the mixture.

reactive extruder See **extruder, reactive-processing.**

reactive injection molding See **reaction-injection molding.**

reactivity See **polymer reactivity.**

reaction viscosity See **processing, reaction viscosity.**

reaction, zero-order A reaction for which a reaction rate is independent of the concentrations of the reactants. An example is a photochemical reaction in which the rate is determined by the intensity of light.

reaction, Zimmermann See **chemical reaction, Zimmermann.**
reactor, breeder A nuclear reactor that produces more nuclear fuel than it consumes. See **synergism.**
reactor technology Reactors are employed in polymer manufacture in the preparation of feeds and the polymerization reactions (bulk, emulsion, etc.). They comprise the underlying engineering principles of chemical-reaction engineering and the practices used in their applications. In addition to stoichiometry and kinetics, reactor technology includes requirements for introducing and removing reactants, efficiently supplying and withdrawing heat, accommodating phase changes and material transfers, ensuring efficient contact among reactants, and providing for catalyst replenishment or regeneration. See **composite, boral; exotherm; kinetic; polymerization; polymerization, solution; polypropylene, multiple monomer.**
reactor, vapor-phase A heavy steel vessel for carrying out chemical reactions on an industrial scale where efficient control over a vapor phase is needed—for example, in an oxidation process.
reactor volatility See **devolatilization.**
reagent Any substance used in a reaction to detect, measure, examine, or produce other substances.
reagent resistance The chemical resistance ability of a plastic to withstand exposure to acids, alkalis, solvents, and other chemicals.
reagent limiting The reactant used up first in a reaction.
real time The present time or as fabrication is occurring.
Reaumur (R) A temperature in which 0 is the freezing point of water and 80 is its boiling point. See **temperature.**
rebuilding and repair See **manufacturing, remanufacturing/rebuilding; screw rebuilding and repair.**
recessed letter/decoration Letters and other designs are depressed in a mold or roll so that when plastic is processed they will be incorporated in the finished product. See **casting; decorating; extruder roll; mold cavity.**
recipe A formula, mixing procedure, and any other instructions needed for fabricating a product. See **formula.**
reciprocating screw See **injection-molding machine, reciprocating-screw.**
reciprocity See **customer reciprocity.**
reciprocity law See **photochemical reciprocity law.**
reclaim Also called *regrind material.* See **granulator; recycling.**
reclamation The recovery, recycling, and reuse of scrap materials (plastics, etc.). See **chemical reclamation; recycling.**
recoatability The application characteristics of a polish and the appearance of a film after successive coatings to part's surface. See **coating.**
recognition threshold The lowest physical intensity at which a stimulus is correctly identified a specific percentage of the time.
recommended practice A definitive, standardized set of instructions for performing one or more specific operations or functions other than the identification, measurement, or evaluation of a material. See **standard.**
recording media Various media formats use large amounts of plastic extruded films (usually thermoplastic polyesters) and injection-molded products (usually polycarbonate disks and polystyrene cases). Included are the VHS videotapes used with VCRs, analog audiotapes for audiocassettes, CDs, data storage on floppy disks sold for software distribution, and DVDs. See **compact disc; digital versatile disk; phonographic record.**
recording musical disk A PVC compound is used with modified compression molding techniques, injection molding, and other processes. See **phonographic record; polyvinyl chloride plastic.**
recoverable resource A material with physical or chemical properties that allow it to be reused, recycled, or incinerated to produce energy. See **material, recovered; recycling; resource.**
recovered material A material or by-product that has been recovered from solid waste, but not including those materials and by-products generated from and commonly reused within an original manufacturing process (industrial scrap).
recovery The degree to which a plastic or elastomer product returns to its normal dimensions after being distorted. See **elastic recovery.**
rectification The purification or enrichment of a liquid by distillation.
recyclable Scrap from many different plastics can be reprocessed into products. It includes industrial scrap, preconsumer, and postconsumer plastics. One of the many advantages of plastics compared to other materials is their flexibility of recycling options. There are mechanical machines (granulators for different materials and products based on thickness, degree of hardness, etc.), energy-recovery systems (energy thermal reclamation), chemical recycling systems, and others. Deciding the method to be used involves factors such as ecology, practicability, economics, applications, and common sense. Also called *secondary plastics.* See **contamination; material, recovered; plastic, reformulated; postconsumer; preconsumer; recoverable resource; recycling method, economic evaluation of; resource, renewable; waste; waste, industrial.**
recyclable coalition See **energy, law of conservation of; waste coalition.**
recycle The return of discarded products or material scrap to the materials cycle.
recycled blown film scrap See **extruder blown-film scrap.**
recycled carpet To reduce the nearly 3.5 billion pounds of carpet that are disposed of annually in the United States, carpet dealers collect used carpets and recy-

cle them into 100% vinyl/nylon fabric composite plastics carpet backing material. It is extruded into the backing material. See **nylon plastic; polyvinyl chloride plastic.**

recycled film and sheets; scrap and rejected products returned to production. The reuse of this scrap requires it to be formed either as flakes (with high bulk density) or as granulated material obtained from plastic compactors and special-purpose extruders. For size reduction of film, maximum demands are made on the efficiency and mechanical strength of the granulator used since high cutting forces are required. Also important is the cutting gap between the stationary and rotating knives. The usual gap for film is 0.2 to 0.3 mm. Suitable granulator screens of small size openings, often not more than 3 mm in diameter, are required to obtain a high-bulk density of the film flakes. Small screen size reduces the obtainable granulator throughput.

recycled paper The EPA defines recycled paper as having a minimum of 50wt% recovered materials with no requirement on postconsumer waste. However, private industry has a broad definition that allows for many kinds of recycled papers. In landfills, preconsumer or postconsumer waste is deinked (removal of ink). With petroleum printing inks in the papers, biodegraded papers leave inks that are major contaminates. See **biodegradable; landfill and degradation; paper; printing ink.**

recycled plastic Plastic that has been used to fabricate parts; scrap or flash that was granulated for recycling. Records should be kept as to the number of times materials are recycled to determine if or when changes occur in processing or performance. Also called *regrind* or *recovered plastics*. See **air entrapment; granulator; plastics cradle-to-grave; plastic, reprocessed; waste plastic.** Organizations worldwide have developed definitions. For example, the ASTM defines *recycled plastics* as processed or reconstituted plastics or those plastics composed of postconsumer material and recovered material that may or may not have been subjected to additional processing steps of the types used to make products, such as recycled regrind. Industry scrap includes what is commonly referred to as *trim* or *regrind* in plastic production, which is not considered recycled material. See **definition.**

recycled plastic identified Different organizations worldwide have developed identification systems. For example, the SAE has a system for Marking of Plastic Parts (SAE Document J-1344). See **bottle code system; container code system; *Unwritten Laws of Engineering: The Professional Code for Engineers.***

recycled-plastic properties When plastics are granulated, processability and performance can be significantly reduced. Thus it is important to evaluate the characteristics of the recycled material. Additives can be added to improve performance. See **plastic, virgin; recycling; recycling size reduction.**

recycled waste with screen pack See **extruder screen pack.**

recycle heat history See **residence time.**

recycling Most processing plants have been reclaiming or recycling reprocessable thermoplastic materials such as blown-film trim, scrap, molding flash, rejected products, and so on. Thermoset plastics (not remeltable) have been granulated and used as filler materials. The goal is to significantly reduce or eliminate any trim or scrap because it has already cost money and time to go through a fabricating process and granulating adds more money and time. Also it usually requires resetting the process to handle it alone (or blending it with virgin plastics) because it does not have uniform particle sizes, shapes, melt-flow characteristics, and properties.

Since scrap can be a mixture ranging from fine dust to large irregular chunks of different shapes and thicknesses, it is important to use a granulator that provides the most uniformity and the least damage to the scrap. Overheating during the cutting action of the granulator causes the most damage; for heat-sensitive plastics cryogenic granulating is used. A granulator that handles soft plastics will not work well when granulating hard plastic. One that handles thin plastic is not the proper type to handle thick plastic; size, and shape (bottles, solid handles, etc.) has an influence. Keeping the scrap clean before and after granulating is a requirement. Recycling will reduce performance properties. The amount of reduction can be very slight to undesirable amounts. Granulated plastics that have been significantly degraded may or may not be reformulated by the addition of stabilizers, pigments, plasticizers, fillers, reinforcements, and other additives. Certain blends, particularly the general-purpose commodity plastics, can be blended with additives to improve their reduced processability or product performances. This type of action is considered for improving granulated material that has lost too many of its properties. Also called *regrind* and *reclaiming*. See **bottle, opaque milk; packaging, loose-fill plastic; plastic, reformulated; plastic, reprocessed.**

recycling cost If recycling could be supported by the sale of materials, private entrepreneurs would have developed these programs decades ago in major markets. Recycled materials have been saleable because of the local to federal regulations requiring its use. See **recycling limitations; recycling method, economic evaluation of; recycling limitations.**

recycling and environment See **environment and public opinion; plastic, long-life.**

recycling and lifecycle analysis A lifecycle environmental analysis provides information about a product, from raw materials, through fabrication products, and after their useful lives. Issues that arise include recycling of process and scrap materials, release of water pollutants and emission of gaseous and particulate pollutants, disposal of nonrecyclable and hazardous waste, disposition of toxic wastes, and costs. See **plastic, long-life.**

recycling and sense Recycling, incineration, and land fill choices must be made based on practicality and economics. A good case can be made for incineration on a volumetric mass (reducing recycle to ashes that are buried under controlled conditions) and reclaiming thermal properties or energy. See **plastic and pollution; plastic, long-life; risk, acceptable.**

recycling, automatic-sorting The goal with plastic scrap or waste has always been to speed throughput, improve its quality, and add value through sorting. The challenge in automating plastics reclaim is to integrate separate technologies that require devices for separating, detecting, and aligning. The major problem continues to be the cost of setting up the complete operation from collection to output sales. See **bottle sorter, optical; sensor, inductive and capacitive proximity.**

recycling baling See **material handling baling.**

recycling, chemical (CR) Material recycling can conflict with energy recycling. CR is actually an intermediate technique between recycling and burning that seeks to break down the polymer molecules in various ways into low-molecular substances that can be used to manufacture plastics again. Thus, chemical recycling is recommended when mixtures of plastics cannot be physically separated or plasticated. CR processes can recover 75 to 85% of energy as compared to 55 to 75% with incineration. This technology is well established as reported by various organizations such as the Belgium-based Association of the Plastics Manufacturers in Europe. Reverse polymerization recreates feedstock and fuels. This recycling can provide advantages that overcome conventional mechanical recycling efforts such as costly sorting, quality, and developing markets for recycled plastics. See **chemical reclamation; gasification; hydrogenation; incineration; pyrolysis; recycling method, economic evaluation of; recycling, tertiary.**

recycling commingled plastic **1.** Recycling of plastics not sorted by type in a waste system. **2.** Recycling by melting unsorted plastics together. See **plastic and lumber.**

recycling, community There are three main types of recycling programs: curbside collection programs, drop-off centers, and buy-back centers.

recycling, cryogenic Recycling certain types of plastics by freezing them to prevent overheating during granulating and to help separate plastics. For example, a cryogenic recycling line can be used to clean PET beverage bottles and HDPE basecup flakes. Cryogenic cleaning uses liquid nitrogen at −200°F (−129°C) to freeze PET and HDPE flakes, which is hurled by high-speed vanes against a steel impact plate. This action pulverizes any frozen glue and releases labels. At such low temperatures, PET and HDPE are not affected, but PVC (from other bottles) crumbles to the consistency of sugar, allowing it to be mechanically screened out of the PET and HDPE. See **cryogenic; deflashing, cryogenic.**

recycling, electrokinetic Using an electric arc to break down plastic waste into useful industrial gases.

recycling energy balance When compared to other materials, plastics have much lower energy consumption requirements from feedstock manufacture to fabricating the finished product. See **energy.**

recycling energy consumption Plastics have the lowest energy consumption in the recycling processes of about 2 MJ/kg (2 to 2.5 MJ/I) and the highest recovery energy content of about 42 MJ/kg. Some comparisons are as follows: (1) Processing waste paper requires 6.7 MJ/kg, and as a general rule about twice as much paper is needed compared to plastics for comparable applications. (2) In glass production, using about 10% of recycled glass reduces the energy consumption of the process by only about 2%; thus the use of recycled glass requires about 8 MJ/kg. The comparative figure is higher when considered in relation to each product, as one needs about 10 to 20 times as much material compared with plastics. (3) The energy requirement for processing scrap steel and tin-plate is about 6 MJ/kg. (4) Aluminum recycling requires about 50% of the energy needed to make a product from virgin aluminum—about 50 MJ/kg. See **energy consumption.**

recycling, energy saver Insulation is the largest single application for plastic virgin or recycled foam with building insulation being very significant. See **energy and plastic.**

recycling fact and myth It is not possible to recycle everything, as some zero advocates claim. Not only is 100% recycling not attainable, but it is not even good for the environment. While the United States is recycling at an average of about 27wt% of its trash, most areas are not going higher than 30 to 35%. (1) At least 25% of trash is simply not recyclable, and if communities want to even reach 50% recycling, about two-thirds of every currently recyclable item would need to be recovered. (2) Only a few of about 50 identifiable items are present in significant amounts, such as cardboard boxes at 13% and newspapers at 6%. Most represent only about 1% of trash so that recovering them would create great cost and inconvenience to consumers and waste handlers. (3) To increase recycling rates dramatically many items would have to be trucked greater distances, and more resources would be needed to clean and process dirty trash, which would negatively affect the environment. Recycling is a mainstream waste-management tool that communities should continue to pursue, but high recycling rates could be counterproductive from environmental and economic standpoints. See **plastic myth and fact; waste.**

recycling foam See **packaging, loose-fill plastic.**

recycling history The first LDPE bottle that was blow molded by Plax Corp., Hartford, CT, used scrap recycled polyethylene plastic in 1942. Goodyear had a two-piece suit and matching tie made from recycled 2-liter PET bottles in 1978. See **plastic history.**

recycling, industry See **World of Plastics Reviews: Challenge 2000—Making Plastics a Preferred Material.**

recycling, integrated Various systems are used. For example, a dual plasticator system combines compounding steps for processing thermoplastics. Recycled plastic is melted in one preplasticizing unit and then fed into a self-cleaning melt-filtration system. It eliminates collecting impurities through a secondary discharge. A fine-mesh (50 micron) screen gives a high degree of purity. A pressure and time control device regulates automatic filter cleaning, while a degassing unit removes traces of solvents and liquids. A second plasticizing unit supplies virgin plastics and additives. The two melt streams are blended in a melt accumulator and can be located upstream of an extruder or injection molding machine.

recycling kerf See **cut, kerf, and registration.**

recycling limitations Logistics, technology, and material properties determine whether it is plausible to reclaim and reuse plastic wastes. Logistic criteria cover the conditions of accrual according to location and quantity. Technological criteria are the purity of type plastic, cleanliness, and geometry (basic shape and uniformity). Property criteria result from the extent of damage to the material during recycling. See **recycling cost; recycling method, economic evaluation of.**

recycling method, economic evaluation of Recycling methods are influenced by factors such as quantity involved, weight involved, size and shape, costs, and continued availability of material. Methods include pyrolysis and repolymerization. Energy can be released through incineration or chemical recycling that can be combined with production of electricity or hot water. The processes used include depolymerization to thermal liquefaction and gasification (back to feedstocks or intermediates), chemical pyrolysis, chemical depolymerization such as methanalysis and glycolysis, alcoholysis, catalytic cracking, gasification, hydrogenation, hydrolysis, and thermal steam of plastics. Each technique has advantages and drawbacks. Some require careful plastic sorting of mixed materials and cleaning.

The choice of whether to recycle to materials or energy has to be determined by an economic audit. Recycling is preferable to landfill practice, which is increasingly costly and which does not use the favorable properties of plastics. Municipal authorities have to consider the economics of recycling operations, taking into account the cost of landfill. Factors to consider are revenue from recycled materials or produced energy, cost of recycling, savings from nondisposal in landfill, and cost of disposal in landfill of the remaining tonnage after recycling. While recycling can save energy and resources in the manufacturing process, getting recyclables to market and then processing into products also uses energy and generates waste that must be managed. The use of fuels and the environmental impact of preparing, collecting, sorting, and transporting recyclables should be considered when developing an audit. See **chemical reclamation; cracking; energy reclamation; gasification; hydrogenation; hydrolysis; polymerization, de-; pyrolysis; recycling, chemical; recycling, electrokinetic; recycling limitations; waste, pressure-cooking.**

recycling mixed plastic Methods used for handling mixed plastics parts include (1) selective collection of parts (selective picking by infrared spectroscopic identification, light optical identification, geometrical identification by hand), (2) separation of granulates and ground stock (floating-settling trough or separating column, liquid cyclone, wind sifting, flotation, electrostatic separation, extraction, melt separation), (3) degradation (pyrolysis, reduced oxygen incineration, hydrolysis, methanalysis, glycolysis, hydrogenation), (4) material recycling inconsistent with plastics characteristics (building and construction aggregates, soil improving additives), (5) processing in a mixed phase (physical compatibility improved, cross-linking, fine dispersion), and (6) energy recycling (refuse and waste incineration, energy recycling of the pyrolysis products).

Various approaches are used to improve performances or properties of mixed plastics, such as (1) additives, fillers, or reinforcements (use specific types such as processing agent, talc, short glass fibers), (2) active interlayers (cross-linking, molecular wetting), and (3) dispersing and diffusing (fine grinding, enlarging molecular penetration via melt shearing).

recycling packaging material See **environment and public opinion.**

recycling polystyrene The FDA in 1990 approved polystyrene plastic recycled scrap for use in egg cartons, meat trays, fast-food containers, school lunch trays, and foam beverage cups. Until that time, recycled PS had been restricted to VCR tape cases, office accessories, and, when combined with other plastics, lumber, traffic signposts, and car stops.

recycling polyurethane Recycling and recovering energy from PURs has been a commercially viable technology. A major factor that aids the recycling is that two-thirds of production is used by just four major industries—transportation, furniture, construction, and bedding.

recycling polyvinyl chloride Despite its economic and environmental advantages, vinyl continues to come under fire in Europe and the United States because of lack of knowledge about recycling and incinerating vinyls and the economics of their uses. Automatic sorting systems are used to separate vinyls from other plastics for recycling. Proper incineration and scrubbing techniques reduce the already negligible (and ability to capture) emissions.

recycling postconsumer plastic Recycling is accomplished by conventional and specialized methods. The major problem is handling the mixed or commingled plastics. Techniques are available to separate the plastics and other materials. Important are the available methods for cleaning materials. Very important is the relatively high cost to operate certain systems and obtaining a return on investment. See **postconsumer; recycling cost; recycling method, economic evaluation of; recycling limitations.**

recycling rasp See **waste rasp.**

recycling, refinery The introduction of plastic scrap or waste into a refining unit to crack the polymer chains into lighter fractions comparable to those found in the refinery stream.

recycling reinforced plastic See **sheet molding compound and bulk molding compound recycling.**
recycling rubber See **vulcanization, de-.**
recycling separator Equipment that separates recycled plastics, such as screens that separate by size and screens with vibrators to remove fines, angel hair, and other contaminants. See **material, cutting burr-free.**
recycling size reduction The size reduction exerts a substantial influence on the quality of the recycled plastics. Economical size reduction requires a machine that permits a flexible solution to any problems. Depending on the material to be processed, use is made of one of the following size reducers: roll cutters/shredders; slicers, guillotine shears; and screw cutters. See **material handling.**
recycling SMC and BMC See **sheet molding compound and bulk molding compound recycling.**
recycling steel with vinyl scrap The zinc and tin coatings on galvanized steel, such as that used for automobile bodies, have always interfered with recycling the metal back to its original purity. The University of Cambridge in the United Kingdom has developed a process using vinyl scrap to remove the zinc and tin coatings. The process involves heating vinyl scrap with the steel to produce hydrochloric acid (HCl) under controlled conditions. Through thermal oxidation, the zinc oxide, which forms on the steel, reacts with HCl to create zinc chloride. The zinc chloride is collected from the process, and the steel is ready to be recycled. This same process can be used to remove tin coatings on steel cans. See **polyvinyl chloride plastic.**
recycling technology See **recycling cost; recycling; recycling limitation; recycling method, economic evaluation of.**
recycling, tertiary Recovery of reusable chemical products by chemical modification of plastic scrap or waste. See **recycling, chemical.**
recycling, thermal reclamation Waste-to-energy reclamation via incineration or chemical recycling. See **energy reclamation.**
recycling waste The methods used in recycling plastic wastes include (1) material recycling by mechanical means; (2) material recycling to feedstock by petrochemical processes (pyrolysis, hydrogenation), thermal degradation, and chemical degradation; and (3) energy recovery by municipal waste incinerator, coincineration (concrete, sludge), monocombustion, and fuel (pretreated). See **chemical reclamation; density; recycled material property; recycling method, economic evaluation of; waste compaction.**
recycling water See **hydrological cycle.**
redox A redox catalyst is one entering into an oxidation-reduction reaction. A contraction of the term *oxidation-reduction.* Plastics formed by such reactions are sometimes called *redox plastics.* See **chemical reaction, half; electrochemical reaction; equivalent; reaction, redox; solution volumetric analysis.**
redox potential The voltage difference of an inert electrode immersed in a reversible oxidation-reduction system measuring the state of oxidation of the system. Also called *oxidation-reduction potential.* See **electrical volt.**
redox potentiometer The neutral electrode probes that are used to measure the solution potential developed as a result of an oxidation or reduction reaction.
redox system A chemical system in which reduction and oxidation (redox) reactions occur. See **redox.**
redox titration A titration characterized by the transfer of electrons from one substance to another (from the reductant to the oxidant) with the end point determined colorimetrically or potentiometrically.
reduced viscosity See **viscosity, reduced.**
reducing agent A substance that can donate electrons to another substance or decrease the oxidation numbers in another substance. See **zirconium hydride.**
reducing waste See **waste, source reduction.**
reduction The process in which an atom gains one or more electrons or, more generally, decreases its oxidation number in a reaction.
reduction gear See **extruder drive.**
reduction of area See **test area reduction.**
reduction potential, standard The voltage associated with a reduction reaction at an electrode when all solutes are 1 M and all gases are at 1 atm.
reduction, volume See **solid-waste volume reduction.**
reengineered See **engineered, re-.**
refinery See **coking; distillation fraction; oil.**
refining See **plastic material refining.**
reflectance See **coefficient of scatter; Fresnel lens.**
reforestation See **resource, renewable.**
refractive ceramic fiber See **fiber, ceramic; fiberglass.**
refractiveness Light absorption in the surface of the material. See **light index of refraction; test, nondestructive transparent medium light schlieren.**
refractivity The refractive index minus one. Specific refractivity is given by $(\eta - 1)/d$, where η = refractive index and d = density. See **light index of refraction.**
refractory An earthly, ceramic material of low thermal conductivity that is capable of withstanding extremely high temperature (1,650 to 22,000°C) without essentially any changes. See **ceramic.**
refractory, brick A highly heat-resistant and nonconductive material that is used for furnace linings in glass and steel industries' processing ovens and other applications where temperatures above 1,600°C (2,910°F) are involved. The first fired bricks occurred about 3,000 B.C. in Mesopotamia where their use included building structures and underground sewers. See **sewer rehabilitation.**
refractory furnace See **fiberglass production.**
refrigerant See **ethylene glycol; polychlorofluorocarbon.**
refrigerator liner forming See **thermoforming.**
refuse Alternate name for *solid waste.* See **waste.**

refuse-derived fuel (RDF) Fuel pellets that have been converted from organic waste. See **energy reclamation.**
refuse reclamation See **reclamation.**
regenerated cellulose See **cellophane.**
regrind See **recycling.**
registration, cut See **cut, kerf, and registration.**
regulation See **legal matter; quality system regulation.**
reinforced molding compound A compound that is supplied by raw material producers or prepared in plants in the form of ready-to-use materials, as distinguished from *premix*. See **compound, premix.**
reinforced plastic (RP) Combinations of plastic (matrix) and reinforcing materials that predominantly come in fiber forms such as chopped, continuous, woven and nonwoven fabric, powder, and flake. They provide significant property and cost improvements over the individual components. The primary benefits include high strength, oriented strength, lightweight, high strength-to-weight ratio, high dielectric strength and corrosion resistance, and long-term durability. The term *composite* denotes the thousands of different combinations of two or more materials that include RPs. Composites that incorporate plastics are called *plastic composites*, but the more descriptive and popularly used worldwide term is *reinforced plastic*. Annual U.S. consumption of all forms of RPs is over 3½ billion lb (1.6 billion kg). Also called *composite*. See **composite; filament winding; laminate; reinforcement.**

Both thermoset plastics and thermoplastics are used. At least 90wt% use glass fiber, and about 45wt% use TS polyester plastic. This RP market started in 1940 using contact or low-pressure TS polyester-plastics, glass-fiber fabricating systems. Today various plastics with different reinforcements have been used with many different RP processes. These products have gone into ocean waters, on land, and into the air, including on the moon and in spacecraft. See **fabric; fiberglass; infrastructure; plastic material type; polymerization, photo-; preform process; reinforcement; roving; sheet-molding compound; thermoplastic; thermoset plastic; yarn.**

The RP industry is a mature industry. Improved understanding and control of processes continue to increase performance and reduce variability. Fiber strengths have risen to the degree that two-dimensional and three-dimensional RPs can produce very high strength, and stiff RP products having long service lives. Thermoplastic RPs (RTPs), even with their relatively lower properties when compared to thermoset RPs (RTSs), are used in about 55wt% of all RP parts. The RTPs are practically all injection molded with very fast cycles using short glass fibers that produce highly automated and high-performance parts. Included in these RTPs are stampable reinforced thermoplastics. See **injection molding; reinforced plastic, injection molding; reinforced plastic process; stamping reinforced thermoplastic.**

reinforced plastic, advanced (ARP) A plastic matrix that is reinforced with very-high-strength, high-modulus fibers or other properties. Examples of these type fibers include carbon, graphite, aramid, boron, S-glass, and Zen-Tron-glass. ARPs can provide the designer with specific properties or characteristics such as strength, stiffness, and lower density used in different environments. They can be at least 50 times stronger and 25 to 150 times stiffer than the matrix. For example, ARPs can possess the desirable properties of low density (1.4 to 2.7 g/cm^3), high strength (3 to 5 GPa), and high modulus (60 to 550 GPa). With proper processing these ARPs provide certain properties equal or exceeding those of most other materials. See **design, reinforcement; plastic, advanced; plastics, theoretical versus actual values of; vapor-liquid-solid process.**

reinforced plastic autoclave molding Very high pressures can be obtained for processing RPs by placing a vacuum bag-molding assemblage in an autoclave. The process may or may not employ an initial vacuum. Air or steam pressures of 100 to 200 psi (690 to 1380 kPa) are commonly achieved. If still higher pressures are required and the danger of extremely high pressures is to be avoided, a hydroclave may be used, employing water pressures as high as 10,000 psi (68.9 MPa). The bag must be well sealed to prevent infiltration of high pressure air, steam, or water into the molded product. See **autoclave molding operation; reinforced plastic, press clave.**

reinforced plastic bag molding Applying an impermeable tailored flexible bag (parting film, etc.) over an uncured thermoset RP part, sealing the edges (bagging), and introducing compressed air pressure (or water) and heat around the bag. This technique is applied with other RP fabricating processes. The side next to the mold can have a "perfectly" smooth finish duplicating the mold cavity surface. The other side can be rough to relatively smooth depending on what and how the reinforcements are laid up and how much effort was used to remove air pockets, compress the plastic, etc. See **blanket; bleed; filament winding prepreg and bag molding; plastic, contact pressure; reinforced plastic lay-up, wet; reinforced plastic pressure bag molding; reinforced plastic separator; reinforced plastic vacuum-bag molding; reinforced plastic void content**. The molding dam is a boundary support or ridge used to prevent excessive edge bleeding or plastic runout of the material and to prevent crowding of the bag during curing. Expendable material includes bag, bag sealers, bleeder plies, breather plies, manifold plies, peel plies, and release fabrics.

The patented Hinterspritzen process allows virgin or recycled thermoplastics, such as PP or PC/ABS, to thermally bond with the backing of multilayer PP-based fabrics, providing good elasticity. This one-step molding technique provides a low-cost approach for in-mold fabric lamination that range from simple to complex shapes.

To ensure release of bleeder material from a bag-molded cured part and to form a flexible diaphragm (bag) over the lay-up during the cure of the TS plastic, a parting film is used. Parting films may include polyvinyl alcohol, polyvinyl fluoride, thermoplastic polyester, polyvinyl chloride, polyurethane, and silicone plastic. Selection of the parting film takes into account the type of plastic being processed, curing temperature and pressure, contour or complexity of the part, and the shrinkage characteristics of the film.

reinforced plastic binder The plastic agent applied to fiber constructions (mat, preforms, etc.) to bond and hold the fibers in their arrangement prior to laminating or molding.

reinforced plastic bleeder cloth A woven or nonwoven layer of material that is used in the manufacture of RP parts to allow the escape of excess plastics and gases during curing of thermoset plastics. It is not part of the final product.

reinforced plastic bleed, zero See **zero bleed.**

reinforced plastic blow molding See **blow-molding, extruder, reinforced-plastic.**

reinforced plastic, bulk-molding compound (BMC) A molding compound (extruded log) that is not produced in sheet form. It consists of the mixture used in sheet-molding compound, except that it contains only short fibers. Injection-molding machines are used with special screw designs and some type of ramming system to feed the screw. Also called *dough-molding compound* (DMC). See **alkyd molding compound; blender, dough; bulk molding compound; injection molding, bulk molding compound; mixer-blender with impeller; sheet molding compound and bulk molding compound recycling.**

reinforced plastic characterization RPs can be characterized in many different ways, such as by type and construction of reinforcement used or by impact and fatigue strength properties. Testing for tensile stress-strain (S-S) properties over a range of high-test rates with areas under the S-S curves is a potential method for estimating relative toughness. Comparing fatigue strength for notched and unnotched conditions at various ratios of minimum to maximum stress is useful in structural design. Depending on construction and orientation of stress relative to reinforcement, it may not be necessary to provide extensive data on time-dependent stiffness properties since their effects may be small and can frequently be considered by rule of thumb using established practical design approaches. When time-dependent strength properties are required, creep and other data are used most effectively. Many RP products have had life spans of many decades, including products that have been subjected to different dynamic loads in many different environments from very low temperatures to very high corrosive conditions. See **creep; directional property; fabric; fatigue; fiber; plastic; stress-strain curve; tensile strength; testing.**

reinforced-plastic charring Heating in air to reduce the plastic to ash, allowing the glass-fiber content to be determined by weight. See **muffle furnace.**

reinforced-plastic cocuring Curing an RP or laminate and simultaneously bonding it to some other prepared surface, such as a decorative lay-up or a printed circuit during its curing cycle. Also curing together an inner and outer tube of similar or dissimilar RP combinations after each has been wrapped or wound separately. There is also the joining of two cured tubes by adhesive bonding, which is referred to as *secondary bonding*. See **bonding, secondary.**

reinforced plastic coin test See **reinforced plastic test; test, coin impact.**

reinforced plastic compaction The application during different fabricating processes of a temporary vacuum bag to remove trapped air and compact the lay-up, which usually includes manual or automatic rolling out of the air bubbles and ensuring compactness. See **compaction.**

reinforced plastic compression molding See **compression molding.**

reinforced plastic contact molding A process for molding RPs in which the reinforcement and plastic are placed on a mold. Cure is either by using a catalyst-promoter system at room temperature or by heating in an oven without pressure or using very little (contact) pressure. Also called *open molding* or *contact-pressure molding.*

reinforced plastic content See **plastic content.**

reinforced plastic cost A major cost in the production of RPs, going from the design concept to the finished product, is materials of construction, which can range from 40 to 90% of the total cost. Understanding how best to use the materials based on the design and processing requirement calls for recognizing situations in which certain approaches may be used and developing problem-solving methods to fit specific design requirements. An important criterion is to understand and properly apply the interrelations of design requirements with materials of construction and fabricating methods. RPs have not come near to realizing their great potential in a multitude of applications, usually due to cost limitations.

reinforced plastic coupling agent A chemical that reacts with the reinforcement and plastic matrix to form or promote a stronger bond at their interfaces. See **fiberglass binder/sizing coupling agent; titanate coupling agent.**

reinforced plastic curing See **cure; curing stress; thermoset plastic curing, dielectric monitoring; thermoset plastic curing, fiber-optic sensor.**

reinforced plastic curing, UV See **polymerization, photo-.**

reinforced plastic cutting Generally two steps are required for RP cutting: (1) using a knife edge hardened with material such as tungsten carbide and (2) custom designing the bushing and knife for each type and shape of material to be cut. The actual type of cutter that is used depends on the type of fiber or fabric with or without the plastic matrix to be cut. See **cutter.**

reinforced plastic debulking Compacting a lay-up, particularly a thick lay-up, under moderate heat and pressure or vacuum to remove most of the entrapped air, thus preventing wrinkles, ensuring contact with the mold surface, and maximizing properties. See **bulk factor; density, bulk.**

reinforced plastic, decorative See **sheet, overlay.**

reinforced plastic degree of bonding See **adhesive contact angle.**

reinforced plastic design See **design, reinforcement; reinforced plastic.**

reinforced plastic, directional property RP design is optimized by focusing on a material's composition, part geometry, and orientation. A major advantage is that directional properties can be maximized. The arrangement and the interaction of the usual stiff, strong fibers dominate the behavior of RPs with the less stiff, weaker plastic matrix (TS or TP). See **World of Plastics Reviews: Basics and Overviews of Fabricating Processes (Fig. 37, RPs Directional Properties).**

The stress-strain behavior of RPs is frequently fairly linear to failure. For high-performance applications, their first damage occurs at stresses just below ultimate strength. RPs, particularly RTSs (reinforced TSs), are also much less temperature-dependent than unreinforced plastic. Complications arise principally from the directional effects resulting from the fiber construction. When constructed from any number and arrangement of RP plies, the stiffness and strength property variations may become much more complex for the novice. The first damage occurs at stresses just below ultimate strength, but an RP can be properly designed, fabricated, and evaluated to take into account any possible variations. See **directional property; filament winding; orientation.**

reinforced plastic dry fiber A condition where fibers are not fully encapsulated by plastic, resulting in a less than desired fabricated part.

reinforced plastic dry lay-up The process of preimpregnating (prepreg) in a female or male mold cavity that is usually used in bag molding or autoclave and that can include the use of a vacuum within the bag. It also is used in other processes, such as filament winding and compression molding. See **reinforced-plastic lay-up, wet.**

reinforced plastic dwarf width A condition where the crosswise (direction of the pultrusion or machine direction) dimension of a flat surface of the part is less than what the die would normally yield. The problem sometimes is caused by a partial blockage in the die orifice due to a melt buildup or particles from the materials adhering to the die orifice.

reinforced-plastic dwell See **dwell.**

reinforced-plastic extensional-bending coupling A property of certain classes of RPs, such as laminated constructions, that exhibit bending curvatures when subjected to extensional loading.

reinforced plastic fabric construction See **yarn twist, direction of.**

reinforced-plastic fiber aspect ratio See **aspect ratio; reinforcement, disk; reinforcement, whisker; slenderness ratio.**

reinforced plastic fiber content The amount of fiber present with the plastic matrix that is expressed as a wt% or vol% (specific gravity of the RP and the percent fiber by weight, divided by the specific gravity of the fiber, equals vol%). See **reinforced plastic ignition loss.**

reinforced plastic fiber count The number of fibers per unit width of ply.

reinforced-plastic fiber direction Fibers may orient or align in different directions. See **directional property.**

reinforced plastic fiber/fabric finish See **fiberglass binder/sizing coupling agent.**

reinforced plastic fiber mat veil See **reinforced plastic surfacing veil.**

reinforced plastic fiber pattern When fiber pattern on the surface is undesired, surface cover layers that become part of the RP are used. They include very thin scrim mat or cloth and plastic gel coatings. See **fabric scrim; reinforced plastic gel coat.**

reinforced plastic fiber percent by volume The product of the specific gravity of the RP and the percent glass by weight, divided by the specific gravity of the fibers, results in the vol%. Since weights of fibers and plastic differ, the vol% is not the same as wt%. See **reinforced plastic void content.**

reinforced plastic fiber percent by weight An easy way to weigh RP fibers, provided the fibers do not disintegrate, is to burn off the plastic in an oven at least 260°C (500°F) using conventional plastics. Weigh the material before and after the burning to obtain the wt%. See **thermogravimetric analysis.**

reinforced plastic fiber wash Splaying out of woven or nonwoven fibers in the direction of the fiber lay-ups. Fibers are carried out along with bleeding plastic during curing.

reinforced plastic fill-out, lack of An area of reinforcement that has not been wet with plastic. This is mostly seen on the edges.

reinforced plastic, flexible A material that is used with elastomeric materials to produce specially engineered products, such as conveyor belts, mechanical belts, high-temperature or chemical-resistant suits, wire and cable insulation, and architectural designed shapes.

reinforced plastic foam See **foam, reinforced; foamed reservoir molding; injection-molding foam.**

reinforced plastic form and spray See **thermoforming, form and spray.**

reinforced plastic forming surface See **thermoforming, comoform cold forming/molding.**

reinforced plastic gel coat In RP processing a gel coat on the outer surface can ensure a smooth surface appearance and a tough surface. A thin synthetic fiber veil can improve the performance of the gel coat. It is a quick-setting plastic that is gelled prior to reinforcement lay-up. The gel coat becomes an integral part of the finished RP product. See **fabric scrim; reinforced-plastic pregel;**

reinforced plastic surfacing mat; reinforced-plastic surfacing veil.

reinforced plastic ghosting The phenomenon where the outline of an inner panel can be seen on the surface of the outer panel. It is usually caused by the rate of cure of topcoat on an assembly that has a variable thermal mass.

reinforced plastic glass-fiber binder See **fiberglass binder/sizing coupling agent; silane couple agent.**

reinforced-plastic glassiness A glassy, marbleized, streaked appearance on the surface of an RP.

reinforced plastic hairline craze A small fissure in plastic, such as coatings, that is often caused by uneven cooling or curing during processing. See **crack, hairline; crazing.**

reinforced plastic hand lay-up This is the oldest and in many ways the simplest and most versatile process for producing reinforced plastic parts. However, it is slow and very labor intensive. It consists of hand tailoring and placing layers of (usually glass-fiber) mat, fabric, or both on a one-piece mold and simultaneously saturating the layers with a liquid plastic (usually thermoset polyester). Depending on the plastic additives, the material in the mold can be cured with or without heat and commonly without pressure. An alternative is to use preimpregnated, B-stage TS polyester such as sheet-molding compound, but in this case heat is applied with low pressure via a impermeable sheet over the material. See **molding, open-mold; reinforced plastic, lay-up, wet; reinforced plastic squeeze molding; reinforced plastic void content.**

reinforced plastic hardness See **test, Barcol, hardness.**

reinforced plastic ignition loss **1.** The difference in weight before and after burning off the plastic in a reinforced plastic to determine percent weight of plastic in the RP. It is usually expressed as a percent of the original weight of the sample. **2.** The difference in weight before and after burning off the binder or sizing to determine the binder or size weight (ignition loss). See **ash content; fiberglass binder/sizing coupling agent; ignition loss.**

reinforced plastic, injection molding. The reinforced thermoplastics are practically all injection molded with very fast cycles using short glass fibers and producing highly automated and high-performance parts. The TPs used include nylons, acetals, polyethylenes, and polypropylene. Of all the RP materials used, almost 55wt% represent these RTPs. See **injection molding; reinforced plastic; screw wear; stamping reinforced thermoplastic.**

reinforced plastic, interlaminar A material in which two different substances or conditions exist. See **laminate.**

reinforced plastic lay-up, dry Reinforcing material that is placed in a specific position in the mold preimpregnated or plastic coated after its geometric lay-up. See **laminate.**

reinforced plastic lay-up, wet A method of making an RP product by applying a plastic liquid system when dry reinforcement is put in the mold cavity prior to applying heat and pressure. With a room-temperature curing wet thermoset polyester plastic, the curing within its own chemical reaction develops exothermic heat to achieve the complete cure. This type of action is particularly advantageous when a large part is required and oven space is not available. See **exotherm; laminate; reinforced plastic hand lay-up.**

reinforced-plastic let-go An area where adhesion between glass-fiber interlayers has been lost.

reinforced plastic, liquid oxygen compatibility See **polyarylene ether phosphine oxide plastic.**

reinforced plastic, low-profile See **plastic, low-profile.**

reinforced plastic, low-pressure Molding at 200 psi or lower (1.4 MPa).

reinforced plastic machine lockout See **safety, machine-lockout.**

reinforced plastic macro property The gross properties as a structural element without consideration of the individual properties or the identity of the constituents.

reinforced plastic Marco process This process was popular during the 1940s and 1950s. Like resin transfer molding and bag molding, the reinforcements are laid up in any desired pattern. Low-cost matched molds (wood, etc.) confine the reinforcement. A pool of liquid catalyzed thermoset polyester surrounds the mold above its partially opened parting line. From a central opening (hole) a vacuum is applied so that the plastic flows through the reinforcements. With proper melt flow, wet-out of fibers occurs, and voids are eliminated. This method when first used was the reverse of RTM. The Marco method eventually incorporated pressure plugs at the parting line and also had a push-pull action where pressure was applied in the center similar to RTM and use was made of the vacuum pool. Eventually, only pressure was applied through the center hole, which later became known as RTM. See **reinforced plastic resin transfer molding.**

reinforced plastic market See **oil wells, undersea; pipe; reinforced plastic; reinforced plastic, injection molding.**

reinforced-plastic material RP design focuses on material composition in conjunction with reinforcement orientation, as well as product structural geometry. This interrelation affects processing methods, product performance, and costs. Even though there are over 17,000 plastics available worldwide (for all plastic fabricating processes), only a few hundred are used in RPs, and only a few of these are used in most of the RPs. The thermoplastics include principally nylons and polypropylenes, as well as polycarbonates, acetals, and polyesters. Thermosets include predominantly polyesters as well as epoxies, phenolics, and urethanes. See **epoxy plastic; phenolic plastic; plastic, low-profile; polyester plastic, thermoset.**

TSs and RTSs generally are more suitable for meeting tighter tolerances. The crystalline RTPs, particularly unreinforced TPs, can be more complicated if the designer does not understand their behavior. Crystalline plastics generally have significantly different rates of melt flow shrinkage, particularly during injection molding, in the longitudinal melt flow and transverse directions; this is less true transversewise. With reinforcement or certain fillers these differences can be reduced or eliminated. With amorphous TPs basically no difference occurs. Compensation for any potentially undesirable differences can be made during product and mold designs, reinforcement or filler selection, and processing. See **amorphous plastic; commodity plastic; crystalline plastic; engineering plastic.**

Reinforcements are discrete (usually) inert inclusions that are used to significantly improve the structural characteristics of a TP or TS plastic. They can be in continuous forms (fibers, filaments, woven or nonwoven fabrics, tapes, etc.) or discontinuous in form (whiskers, flakes, spheres, etc.). The reinforcements can allow the RP materials to be tailored to the design or the design tailored to the material. When permitted, it is best to use prepreg or molding compounds where the plastic and reinforcement are prepared and ready for fabricating into a product. These materials include sheet-molding compounds, bulk-molding compounds, and stampable sheets. They can be prepared and processed to meet different directional properties or product performances. See **plastic material type; reinforcement; vinyl ester plastic.**

reinforced-plastic material, low-profile plastic See **plastic, low-profile.**

reinforced plastic material, mat See **fiber mat.**

reinforced plastic material, sheet molding compound (SMC) A ready-to-mold glass-fiber reinforced thermoset polyester material that is primarily used in compression molding. See **sheet-molding compound and bulk molding compound recycling.**

reinforced plastic matrix See **plastic matrix.**

reinforced plastic microcracking Cracks that are formed when local thermal stresses exceed the strength of the matrix. Because most microcracks do not penetrate the reinforcing fibers, they are usually limited to only penetrating one thickness of a single ply, particularly with woven reinforcements. See **crack.**

reinforced plastic micromechanics The process of analyzing the mechanical behavior of RPs by considering the properties, concentration, geometry, and packing of the individual components. This contrasts with macromechanics by recognizing the nonhomogeneous nature of RP. By making various approximations of the packing geometry and stress fields within an element of the matrix, the average properties of the element may be calculated.

reinforced plastic micro property The properties of the plastic matrix, reinforcement, and their interface with their effects on the properties of the reinforced plastic.

reinforce plastic modulus versus specific gravity See **modulus versus specific gravity.**

reinforced plastic moisture content Moisture can restrict performance more in RPs in certain applications, than in conventional non-RPs. A good bond must exist between the reinforcement and plastic, otherwise moisture can easily penetrate from any exposed edges that are not properly protected. See **drying; fiberglass binder/sizing coupling agent; test, reinforced plastic moisture-content.**

reinforced plastic mold, elastomeric A elastomer or rubber mold during heat processing can take advantage of its thermal expansion to help form the RP part. See **elastomeric mold; mold, elastomeric.**

reinforced plastic molding Different types and forms of RP materials are molded using various techniques as reviewed in this section for reinforced plastic. See **compression molding; molding; preform process.**

reinforced-plastic molding, autoclave See **reinforced plastic autoclave molding; reinforced plastic press clave.**

reinforced plastic molding compound A plastic that is reinforced with special fillers or fibers to meet specific performance requirements during processing and in the final molded part. See **reinforced plastic bulk-molding compound.**

reinforced plastic molding dam A boundary support or ridge that is used to prevent excessive edge bleeding or plastic runout of the RP and to prevent crowning of bag-molding during cure.

reinforced plastic molding fiber shrinkage A condition in which fibers do not move into or conform to a mold's radii and corners during molding, which can result in voids and dimensional control problems.

reinforced plastic molding, lost-wax A process for making high-performance parts in which a bar (or any shape) of wax is wrapped with RP. After the RP is cured (bag molding, etc.) in a simplified restrictor mold to keep the RP-wax shape, the wax is removed by drilling a hole or removing the end caps and applying a low temperature (so that the RP is not affected). Also called *RP molding, fusible-core.* See **reinforced plastic soluble core molding; soluble core molding; wax, soluble core.**

reinforced plastic molding, match-metal A method of molding RPs in which the material is cured by placing it between male and female metal molds in a way that is similar to that used in compression molding. The method is usually associated with molding parts with large surface areas. Also called *matched-die molding.* See **compression molding.**

reinforced plastic nesting Placing plies of fabric so that the fibers of one ply lie in the valleys between the fibers of the adjacent ply. Also called *nested cloth.* See **laminate.**

reinforced plastic nondestructive test See **test, nondestructive acoustic holography; test, nondestructive carbon fiber reinforced plastic x-ray scanning.**

reinforced plastic open molding See **reinforced plastic contact molding.**

reinforced plastic operator's sequence See **opera-**

tion, manual; operation, automatic; operation, semiautomatic.

reinforced plastic orientation See **directional property.**

reinforced plastic peel ply The outside layer, which is removed or sacrificed to achieve improved bonding of additional plies. See **adhesive peel strength.**

reinforced plastic pipe A pipe that is used where heavy internal and particularly heavy external loads exist, such as underground piping. See **design pipe; pipe market; pipe, deteriorating; sewer rehabilitation; underground pipe.**

reinforced plastic pipe covering See **oil wells, undersea.**

reinforced plastic, plastic-rich See **plastic-rich; reinforced plastic, resin-rich.**

reinforced plastic pregel An intentional or usually an unintentional extra layer of cured plastic on the surface of the RP. This is not the gel coat. See **gel; reinforced-plastic gel coat.**

reinforced plastic preimpregnation The practice of mixing usually thermoset plastic (hot-melt or solvent system; also wet system without solvent) and reinforcement and storing for use at a later time or for shipping to a molder. The reinforcement can be of any style, such as glass-fiber mat or fabric. It is partially cured (B-stage) ready-to-mold material in web form that may have a substrate of glass-fiber mat, fabric, roving, etc.; paper; cotton cloth; etc. With proper storage condition of temperature, their shelf life can be controlled. Also called *prepreg*. See **A-B-C stages; filament winding prepreg and bag molding; impregnation; plastic heat staging; prepreg; reinforced plastic prepreg; sewer rehabilitation.**

reinforced plastic preimpregnation peel ply A layer of open-weave material, usually glass-fiber or heat-set nylon, that is applied directly to the surface of the prepreg lay-up. This peel ply is removed immediately before bonding operations, leaving a clean, resin-rich surface that usually needs no further preparation for bonding.

reinforced plastic preimpregnated pucker See **reinforced plastic prepreg pucker.**

reinforced plastic, premolded The thermoset plastic lay-up and partial cure at an intermediate cure temperature of reinforced chopped fiber or laminated part to stabilize its configuration for handling and assembly with other parts for final cure.

reinforced plastic preply A material lamina in the raw material stage that is ready to be fabricated. It is usually combined with other raw materials before fabrication. It is a fiber system that is placed in position relative to all or part of the required matrix material. When the plastic is combined with the preply, it is called a *prepreg*.

reinforced plastic prepreg A plastic preloaded mat or fabric. See **plastic heat staging; prepreg; reinforced plastic preimpregnation; thermoforming thermoset plastic.**

reinforced plastic prepreg drape The ability of a prepreg or any wet lay-up to conform to a contoured surface.

reinforced plastic prepreg out-life The period of time that a prepreg material remains in a handleable form and with properties intact outside of the specific storage environment, such as outside of the freezer with thermoset prepregs.

reinforced plastic prepreg pucker A local area where the material has blistered and pulled away from the separator film or release paper.

reinforced plastic prepreg staging See **plastic heat staging.**

reinforced plastic prepreg tape Unidirectional prepreg. See **directional property.**

reinforced plastic prepreg tracer A fiber or yarn added to a prepreg for verifying fiber alignment and, in the case of woven materials, for distinguishing warp fibers from fill fibers. See **tracer.**

reinforced plastic press clave A simulated autoclave made by using the platens of a press to seal the ends of the open chamber, providing both the force required to prevent loss of the pressurized medium and the heat required to cure the RP inside. See **autoclave; reinforced plastic autoclave molding.**

reinforced plastic pressure bag molding An adaptation of vacuum-bag molding where the bag and mold are placed in a closed system and are subjected to pressure during the curing cycle. See **reinforced plastic bag molding; reinforced plastic vacuum-bag molding.**

reinforced plastic pressure curing transducer A device that is used for processing thermoset plastics that require pressure monitoring during curing; if not properly applied pressure can cause damage to part quality. Pressure sensors (transducer) located at different sections of the RP can be used in addition to the press pressure gauges. See **transducer, pressure.**

reinforced plastic pressure intensifier A layer of flexible or elastomeric material that is used to ensure the application of sufficient pressure to a location, such as a radius, in a lay-up being cured.

reinforced plastic process Various fabricating processes are employed to produce RP products, which represent about 5wt% of all plastics products. They range in fabricating pressures from zero (contact), through moderate, to relatively high, at temperatures ranging from room to well over 100°C (212°F). Equipment may be simple and low cost or may require expensive, specialized computer control of the basic machine and its auxiliary equipment. Each process provides capabilities such as meeting production quantity (small to large), performance requirements, proper ratio of reinforcement to matrix, fiber orientation, reliability and quality control, surface finish, and so forth versus cost (equipment, labor, utilities, etc.). Common processes are injection molding, pultrusion, compression molding, contact molding (hand lay up, spray, etc.), matched mold methods (modified IM or CM, resin transfer, pressure bag, etc.), spray up, and filament winding. Other processes include autoclave molding, rotational molding, reaction IM reinforced, continuous laminating, and centrifugal casting. Selecting the optimum process encompasses a broad spectrum of possibilities (shape, size, materials used, quantity, tolerance, time schedule, cost, etc.). For some designs only one process can be used, but for others different processes can be used. Each process, like each material of construction, has its capabilities and limitations. Material or product performances are frequently strongly influenced by the process used. See **fabricating process type; ramping; reinforced plastic.**

reinforced plastic processing agent See **mold-release agent.**

reinforced plastic processing, lack of plastic fill-out A condition where reinforcement is not wetted with sufficient plastic. For example, it can occur on the edge of a laminate or pultrusion.

reinforced-plastic processing vent cloth A layer or layers of open-weave cloth that is used to provide a path for a vacuum to reach the RP area being cured so that plastic volatiles and air can be removed. This action also provides a means of applying pressure to the complete RP. Also called *breather cloth.* See **autoclave venting; venting.**

reinforced plastic pultrusion A continuous process for fabricating RPs that usually have a constant cross-sectional shape. The reinforcing fibers are pulled through a plastic (usually TS) liquid-impregnation bath by rollers and then through a shaping die, followed by a curing action. In some systems no plastic bath is used, and the plastic is impregnated in the die, similar to the take-off in extruding wire and cable providing controlled impregnation. See **blow-molding, extruder, reinforced-plastic; extruder wire and cable process, dry cure; prepreg solution process.**

reinforced-plastic pultrusion, black mark A surface black smudge that results from excessive pressure in the die when the pultrusion is rubbing against a die surface that is not chrome plated. It is difficult to remove.

reinforced-plastic pultrusion bow An unwanted condition of longitudinal curvature in pultruded parts.

reinforced-plastic pultrusion braiding Pultrusion with in-line braiding impregnates fibers before they are braided together. The result is a product with special high-performance properties. See **fiber, braided.**

reinforced-plastic pultrusion chip Minor damage to a surface that removes material but does not cause a crack or craze.

reinforced-plastic pultrusion crack A longitudinal crack that occurs within sections of the roving reinforcement. This condition is caused by shrinkage strains during cure that show up in the roving portion where transverse strength is low. Modifying or rearranging rovings can eliminate this problem. See **crack.**

reinforced-plastic pultrusion curing See **thermoset plastic curing, fiber-optic sensor.**

reinforced-plastic pultrusion die Dies are streamlined and have a smooth, polished surface with a chrome plating. See **die, profile; extruder profile die.**

reinforced plastic pultrusion dwarf width A condition in which the crosswise (to the direction of the pultrusion) dimension of a flat surface is less than what the die would normally yield. This condition is usually caused by a partial blockage in the die cavity by built-up or RP particles adhering to the die cavity. This condition is also called a *lost edge* when the flat surface has a free edge that is altered by the build-up.

reinforced plastic pultrusion exposed underlayer The underlayer of mat or roving is not covered by the surface mat. This condition can be caused by reinforcement shifting, too narrow a surface mat, too wide an underlying mat, uneven slitting of the surface mat, necking down of the surface mat, or excessive tension in pulling the surface mat off the processing spindle.

reinforced plastic pultrusion fiber bridging Reinforcing fiber that bridges an inside radius that is caused by shrinkage stresses around such a radius during curing.

reinforced plastic pultrusion fiber prominence A visible and measurable pattern of the reinforcing material on the surface of the pultrusion.

reinforced plastic pultrusion flat A longitudinal, flat area on a normally convex surface that is caused by shifting of the reinforcements, lack of sufficient reinforcement, or local fouling of the die surface.

reinforced plastic pultrusion glassiness A glassy, marbleized, streaked appearance on the surface. Although this condition is visually evident, the reinforcement is fully encapsulated with the plastic.

reinforced plastic pultrusion, shrinkage in Shrinkage that causes inside-radius bridging.

reinforced plastic pultrusion sluffing Scales that peel off or become loose either partially or entirely from a pultrusion. Not to be confused with scraping, prying, or physically removing scale from a pultrusion part.

reinforced plastic reaction-injection molding (RRIM) A molding process that incorporates into the conventional RIM process, reinforcements such as woven or nonwoven fabrics, short glass fibers, glass flakes, and milled fibers. These additives stiffen or strengthen the part and reduce thermal expansion. The usual procedure is to lay out reinforcement in the mold cavity using some type of clamping system prior to the reaction injection molding process occurring. Milled fibers (glass, etc.) can be mixed into one of the liquid reactive material tanks where a continuous stirring action exists. See **fabric; fiber; reaction injection molding; reaction injection molding, structural; reinforcement.**

reinforced plastic, resin-rich A part defect in which a localized area has a drastic reduction in fibers or no fibers at all. See **plastic-rich.**

reinforced plastic resin transfer molding (RTM) Vacuum-assisted RTM can be called *infusion molding.* RTM usually uses liquid thermoset plastic that is transferred or injected into an enclosed mold, normally at low pressures of about 60 psi (410 kPa) in which reinforcement has been placed. The reinforcement is usually glass-fiber woven, nonwoven, or knitted fabric. Plastic flows through the reinforcement targeting to remove air through release ports or openings where its parting line exists. Cure can be with a heated mold or catalyzed so that it develops its own heat based on a prescribed time schedule. See **catalyst; reinforced plastic Marco process; reinforced plastic squeeze molding; SCRIMP**. RTM process conditions are typically determined empirically via molding experiments. Process control using in-mold sensors to measure plastic cure have been developed based on ultrasonic, dielectric, microwave, and spectroscopic methods. Some previously developed sensors suffered in that they measured the average cure over a large volume of the mold and part thickness. Localized sensors have been applied to cure monitoring. See **cure.**

reinforced-plastic rotational molding To strengthen the molded part, reinforcements are added to the compound; the molded parts contain reinforcements. See **rotational molding.**

reinforced plastic scrim cloth See **fabric scrim.**

reinforced plastic SCRIMP process This Seeman Composites Resin Infusion Process (SCRIMP) is a gas-assist resin-transfer molding process. Glass-fiber fabrics, thermoset vinyl-ester polyester plastic, and polyurethane foam panels (for insulation) are placed in a segmented tool. A vacuum is pulled with a bag so that a huge amount of plastic can be drawn into the mold (Marco process approach). Its curved roof is made separately and bonded to the box with mechanical and adhesive fastening. It is similar to various reinforced-plastics molding processes. See **reinforced plastic bag molding; reinforced plastic dry lay-up; reinforced plastic Marco process; reinforced plastic resin transfer molding.**

reinforced plastic separator A permeable layer that also acts as a release film. Porous PTFE-coated glass-fiber woven fabric is an example. It is often placed between lay-up and bleeder to facilitate a bleeder system's removal from the RP or laminate after cure.

reinforced plastic sheet molding compound (SMC) Usually thermoset polyester plastic (generally cross-linked with styrene) with glass fibers and additives such as pigments and fillers that have been compounded and processed into sheet form to facilitate handling in the molding operations. This B-stage material has a long shelf life, particularly when stored in a cool place. See **injection molding, bulk molding compound; molding, sheet molding compound and vacuum-press; polyester plastic, thermoset; sheet molding compound; sheet molding compound and bulk molding compound recycling; thickening agent.**

reinforced plastic sheet molding compound carrier film Usually a nylon or polyethylene film used for the manufacture and storage of SMC. This carrier film is removed prior to molding.

reinforced plastic sheet molding compound doctor box A device on the SMC manufacturing line that contains and uniformly spreads plastic paste over the carrier film.

reinforced plastic sheet molding compound maturation A time period in the manufacture of SMC in which the viscosity of the resin matrix increases from 20×10^3 cp to at least 20×10^6 cp when ready for molding.

reinforced plastic short-term waviness (STW) A surface defect that is usually perceived as orange peel.

reinforced plastic soluble core molding Similar to fusible core molding; the soluble core is dissolved after molding to create a complex hollow part. Various core materials are used. The first all-plastic airplane (1944, U.S. Air Force) used wax to construct rectangular beams cores for the RP sandwich monoque fuselage and wings. See **eutectic mixture; reinforced plastic molding, lost-wax; soluble core molding.**

reinforced plastic spray-up An air-spray gun including a roller cutter that chops usually glass-fiber rovings to a controlled length before they are blown in a random pattern (manually or automatically) onto a surface of the mold. Simultaneously, the gun sprays catalyzed thermoset polyester plastic. The chopped fibers are plastic coated as they exit the gun's nozzle. The resulting, rather fluffy RP mass is consolidated with serrated rollers to squeeze out air and reduce or eliminate voids. A closed mold with appropriate temperature and pressure produce parts. See **preform; thermoforming, form and spray.**

reinforced plastic squeeze molding An intermediate step between hand lay-up and resin-transfer molding. The reinforcement is put into a mold. In turn, the mold is put into an air-bag press (or the equivalent) where the plastic is slowly forced through the mold cavity at low pressures of about 30 to 75 psi (200 to 500 kPa). The RP is cured at room temperature. See **reinforced plastic hand lay-up; reinforced plastic resin transfer molding.**

reinforced plastic stamping See **stamping reinforced thermoplastic; thermoforming, solid-phase pressure.**

reinforced plastic stress analysis See **plastic, smart; stress-strain curve.**

reinforced plastic structure See **infrastructure.**

reinforced plastic surface See **alligatoring; orange peel; plastic, low-profile.**

reinforced plastic surfacing mat A very thin mat, usually 180 to 510 μm (7 to 20 mil) thick, of highly filamentized glass fiber. It is used to produce a smooth surface on reinforced plastics. See **reinforced plastic gel coat; sheet overlay.**

reinforced plastic surfacing veil An ultra thin mat that is similar to a surface mat and usually composed of organic fibers as well as glass fibers. See **fiber mat; reinforced-plastic gel coat; sheet overlay; veil.**

reinforced plastic, symmetrical Lay-up in which the stacking sequence of plies below its midpoint is a mirror image of the stacking above the midplane.

reinforced plastic syntactic cellular plastic An RP compound made by mixing hollow microspheres of glass, epoxy, phenolic, etc. into a fluid thermoset plastic with its additives and curing agents. It forms a moldable, curable, lightweight mass, as opposed to foamed plastics, in which its cells are formed by gas bubbles, etc. Also called *RP syntactic foam* or *syntactic foam.* See **foam; foam, reinforced; microsphere.**

reinforced plastic test See **strain, flexure of fiber; test, laminated curved-bar delamination analysis; test, NOL ring; test, nondestructive acoustic emission; test, nondestructive carbon fiber reinforced-plastic x-ray scanning; test, nondestructive impact RP coin trapping; test, nondestructive ultrasonic.**

reinforced plastic test, extensional-shear coupling A property of certain classes of RPs, such as laminated constructions, that exhibit shear strains when subjected to extensional loading. See **shear strain.**

reinforced plastic test, flexural strength, wet See **flexural strength, wet.**

reinforced plastic test, moisture See **test, reinforced plastic moisture-content.**

reinforced plastic test, temperature See **test, nondestructive temperature differential by infrared.**

reinforced plastic test, shear See **flexural test, short-beam shear; shear strength, short-beam.**

reinforced plastic vacuum-bag molding Reinforced plastics can be prepared for curing in an open mold with a flexible membrane or bag over the RP. A vacuum is drawn inside the enclosure, commonly resulting in atmospheric pressures of 10 to 14 psi (69 to 97 kPa), with or without heat (depending on how the plastic was prepared). The result is a molded part with a very smooth surface against the mold surface. See **compaction; molding, sheet-molding compound and vacuum-press; reinforced-plastic bag molding; reinforced-plastic pressure bag molding; vacuum press.**

reinforced-plastic venting cloth A layer or layers of open-weave cloth that is used to provide a path for a vacuum to reach the area in which an RP is being cured, such that air, volatile, and excess plastics can be removed. It is used in different RP processes. Also called *breather cloth.* See **reinforced plastic; separator; vent cloth; venting.**

reinforced-plastic void content Voids are generally the result of the entrapment of air that exists during the construction of a lay-up, particularly during molding at low pressures. It is possible to have void contents of 1 to 3%. Depending on the part application, voids can cause a reduction in performance and invite moisture. If voids are undesirable, various procedures can be used, such as squeezing out air during lay-up by a roller or spatula manually or automatically or applying a vacuum during molding. See **test, nondestructive temperature differential by infrared; void.**

reinforced-plastic weight, area The weight of a fiber reinforcement per unit area (width times length) of tape or fabric.

reinforced-plastic wet lay-up See **reinforced-plastic lay-up, wet.**

reinforced plastic wet-out The ability of a plastic to saturate a fiber reinforcement in which substantially all voids are filled with plastic. This condition occurs during the soaking of porous materials with liquid plastic when all voids between filaments become filled with the plastic.

reinforced plastic wet-out rate The time that is required for the plastic to fill interstices and wet the surfaces of the fibers. It is usually determined by optical or light transmission instruments.

reinforced plastic wet system RP processes and equipment that incorporate reinforcement impregnation as part of the process prior to entering a die or mold, such as with pultrusion.

reinforced plastic, XTC An RP that combines glass fibers and PET fibers in a mat form that are cut to shape and processed usually by compression molding. The material is similar to sheet-molding compound. Heating XTC causes the PET fibers to flow and reinforce the glass fibers. See **sheet molding compound.**

reinforcement A strong inert material bound into a plastic to improve its properties, such as strength, stiffness, impact resistance, and dimensional shrinkage. To be effective, the reinforcement must form a strong adhesive bond with the plastics; for certain reinforcements special cleaning, sizing, and finishing treatments are used to improve bond. Types of reinforcements include fibers of glass, graphite, boron, nylon, polypropylene, cotton, sisal, and asbestos. Inorganic and organic fibers have diameters ranging from about 1 to over 100 micrometers. Properties differ for the various types, diameters, shapes, and lengths. Their properties range from very low to very high. The designer needs to properly identify which reinforcement is used (as with the plastic). See **carbon black; chemical vapor deposition; design, reinforcement; directional property; fabric, burlap; fiber; fiber carding; fiber, metallic; fiber processing, gel-spinning; fiber, spider-silk; hemp; plastics, theoretical versus actual values of; reinforced plastic; reinforcement, whisker.**

reinforcement and property See **testing and classification.**

reinforcement, disk Reinforcements and fillers in a disk form, including mica, glass, and aluminum. Naturally occurring mica has a variety of chemical compositions and morphologies. Commercial types include wollastonite, muscovite, and phlogopite. The aspect ratio of all the disks plays an important role; high values of 5 to 10 provide for good reinforcements. Lining up and overlapping disks to take advantage of directional properties to date has been achieved in the laboratory but is difficult to set into production. Theoretically, with proper lay-up the highest performance plastics could be obtained. See **aspect ratio; reinforcement, whisker; slenderness ratio.**

reinforcement, natural See **bamboo.**

reinforcement, polyethylene fiber See **fiber process, gel-spinning; fiber process, solution-spinning.**

reinforcement, whisker Whiskers are metallic and nonmetallic single crystals (micrometer-size diameters) of ultrahigh strength and modulus. Their extremely high performances (high melting points, resistance to oxidation, low weights) are attributed to their near perfect crystal structure, chemically pure nature, and fine diameters that minimize defects. They exhibit a much higher resistance to fracture (toughness) than other types of reinforcing fibers. Many different materials have been used (literally hundreds), with diameters ranging from 1 to 25 μm (40 to 980 μin.) and aspect ratios between 100 to 15,000. Processes used to manufacture whiskers include growing them by condensation from supersaturated vapor, from chemical solution, and by electrodeposition. Because they have extremely high costs and are not easy to process with present technology, they have been used primarily in specialty applications, such as aerospace and medical/dental. Matrices include plastics, ceramics, and metals. See **aspect ratio; fiber, carbon; fiber, metallic; slenderness ratio; vapor-liquid-solid process; whisker, metallic.**

reinforcing agent A filler, in fiber and other forms such as flakes or powders, that is used to increase principally mechanical properties of plastics. See **alumina trihydrate; fiber; reinforcement.**

reinforcing filler An additive that modifies principally mechanical properties of the plastics. See **filler.**

relative humidity (RH) The ratio of the quantity of water vapor present in a given volume of air expressed as a percentage. It is also the ratio of the actual pressure of existing water vapor to the maximum possible (saturation) pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage. See **humidity; hygrometer.**

relaxation The time-dependent return to equilibrium of a system or property of a system, that has been displaced from equilibrium by an applied constraint in the context of plastic relaxation. The constraints may be an electric, field (dielectric relaxation), visible or ultraviolet radiation (luminescence depolarization or dynamic birefringence), mechanical stress or strain (mechanical relaxation; a decrease in stress under sustained constant strain), or creep and rupture under constant load. A practical example in mechanical relaxation is the gradual decay of stress in a specimen that is held stretched. See **creep relaxation; dynamic mechanical measurement; spectroscopy, dielectric relaxation; strain relaxation; stress relaxation.**

relaxation time The time required for a stress under a sustained constant strain to diminish by a stated fraction of its initial value. See **elasticity, high.**

relaxation, ultrasonic Relaxation that occurs as a result of ultrasonic irradiation. Irradiation results in a periodic longitudinal compression and rarefaction (a pressure fluctuation) of the material. This may be resolved into isotropic and shear components. The response of a sample to the two components may be evaluated so that effectively such measurements amount to the determination of the moduli at higher frequencies than in other mechanical relaxation methods. Monitoring of this response yields thermodynamic data that can be related to specific conformational changes in the plastic. See **ultrasonics.**

relay A mechanical or electrical device in which a small electric current is made to switch a large device.

relay logic A technique originally used for timing and sequencing operations in processes. It has generally been replaced by computer electronic logic controls.

release agent See **mold-release agent.**

release film An impermeable layer of film that does not bond to the plastic being cured. See **separator.**

reliability The probability that a product will perform its intended function satisfactorily for a prescribed life under certain stated environmental conditions. Quality is the condition of the product during manufacturing or immediately afterward, whereas reliability is the ability of the product to perform its intended function over a period of time. Quality and reliability interrelate because if the quality control program is inadequate, then reliability is affected. See **accuracy; legal matter: plaintiff; legal matter: product liability law; probability; quality; quality level, acceptable; repeatability; sampling acceptable quality level; specification; statistical benefit; statistical material selection, reliability of.**

reliability control system See **control-system reliability.**

rennet A coagulant for milk that is used in the manufacture of casein. See **casein.**

repeatability Most applications are concerned with repeatability that is easier to achieve than high accuracy. Repeatability deals with factors such as how closely the length of a given feed will repeat itself. Repeatability is different in that it does not include the noncumulative errors that an accuracy specification quantifies. Noncumulative errors are caused by factors, such as in a motion drive system, like backlash and hysteresis. Because repeatability assumes that all travel is unidirectional, which is true in almost all cut-to-length applications, the effects of backlash and hysteresis are negligible. See **accuracy; backlash; design accuracy; electric motor, adjustable speed drive; extruder web stretching and tearing; fabricating processing repeatability; hysteresis; motion control system.**

repellent, water See **water repellent.**

reporting See **data-management system; technical writing.**

research and development (R&D) Worldwide R&D assists in designing products, processing equipment, and developing plastic materials allows the plastic industry to continually expand its markets. See **cost-benefit analysis; design; design features that influence performance; empirical; entrepreneur; fabricating process type; invest early; legal matter: patent pooling with competitor; market; medical packaging; military market; performance prediction; plastic; plastic industry size; plastic, long-life; plastic material; plastic material type; process simulator; productivity revo-**

lutionary versus evolutionary developments; specification; technology assessment; technical writing; technology; theory; thermoflow plastic.

research and marketing See **World of Plastics Reviews: Making Marketing Work.**

reservoir foamed molding See **foamed reservoir molding.**

residence time The amount of time that a plastic is subjected to heat during fabrication of virgin plastics such as during extrusion, injection and compression molding, and calendering. With recycled plastics, properties are affected by previous fabrication and granulating heat. This residence time can cause minor to major undesirable properties or variations in properties, of the plastic during the next processing step, or in the finished product. This action can occur even when the same plastic (from the same source) and same fabricating machine are used. Different thermal tests are available and used to meet specific requirements. See **fabricating process; injection-molding machine downsizing; injection-molding screw-rotation speed; material, powder compact; processing via fluorescence spectroscopy; screw length-to-diameter ratio; stress, residual.**

residual deflection Permanent deformation after complete or partial removal of applied force on a product, component, or structure. See **deflection.**

residue Any undesirable material that remains on a substrate after any process step, after the part is in service, etc. See **tailing.**

resilience **1.** The ratio of energy output to energy input in a rapid (or instantaneous) full recovery of a deformed material, usually expressed as a percentage. See **dynamic; elastomer proof resilience; elastoplastic; hysteresis, elastic. 2.** The ability to regain an original shape quickly after being strained or distorted. See **energy.**

resilience, impact The ratio of output to input mechanical energy in a rapid deformation and recovery cycle of the material. See **deformation.**

resin See **plastic.**

resinography The science of morphology, structure, and related descriptive characteristics as correlated with composition or conditions and with properties or behavior of plastics and their products. See **chromatic aberration; collimator; equilibrium centrifugation.**

resinoid A thermoset plastic either in its initial (or temporarily fusible) or in its final (infusible) state.

resin pocket See **pocket, plastic.**

resinous Having the appearance or properties of a resin (plastic).

resin transfer molding See **reinforced-plastic resin transfer molding.**

resistance See **abrasion resistance; chemical resistance; light resistance; rain; thermal resistance.**

resitol A thermoset plastic of the phenol formaldehyde type that passes through a transition stage during the curing process. At this stage, the plastic will soften to a rubberlike consistency under the influence of heat but will not melt. When immersed in alcohol or acetone, the plastic will swell but is virtually insoluble and is referred to as B-stage. See **A-B-C stages; phenolic plastic; thermoset plastic.**

resole plastic A linear phenolic one-stage plastic that is produced by alkaline condensate of phenol and formaldehyde. See **novolak plastic; phenolic plastic; reaction-injection molding, structural.**

resonance **1.** Mechanically, the reinforced vibration of a body exposed to the vibration at about the frequency of another. See **vibration. 2.** In chemistry, the moving of electrons from one atom of a molecule or ion to another atom of the same molecule or ion. See **atom; ion; molecule. 3.** In the terminology of spectroscopy, the condition in which the energy state of the incident radiation is identical with the absorbing atoms, molecules, or other chemical entities. See **spectroscopy. 4.** The use of two or more Lewis structures to represent a particular molecule. See **electron, Lewis acid.**

resonance, draw A form of draw-down failure that is characterized by the wandering or wavering of the edge of a molten film or the loss of thickness uniformly across the width of a coating. See **extruder flat film draw-ratio.**

resonance fluorescence See **spectroscopy, absorption.**

resonant forced vibration A test for performing dynamic mechanical measurements, in which the sample is oscillated mechanically at the natural resonant frequency of the system. Its amplitude of oscillation is maintained constant by the addition of makeup energy. Elastic modulus is calculated from the measured frequency. Damping is calculated from the additional energy required to maintain constant amplitude. See **damping, mechanical; dynamic mechanical measurement; nonresonant forced and vibration technique; modulus, dynamic; vibration, free.**

resonant frequency A frequency at which resonance exists.

resorcinal-formaldehyde plastic A thermoset type of phenol-formaldehyde plastic. It is permanently fusible and soluble in water, ketones, and alcohols. It can provide fast and room-temperature cure.

resource See **oil resources, limited; plastic products, raw material to; recoverable resource; steel resources, limited.**

resource depletion See **vinyl composition tile.**

resource, renewable A natural resource that can be replaced as it is consumed, such as a forest (reforestation) in the lumber industry. See **wood.**

retarder A material used to reduce the tendency of a rubber or thermoset elastomer compound to vulcanize prematurely. See **catalyst, negative; inhibitor.**

reticulate A network or netlike structure. See **foam and process cell structure.**

retort The shape of a type of a simple distillation unit characterized by its glass neck twisted downward.

retortable pouch See **packaging, retortable-pouch.**

return on investment (ROI) The amount of profit expressed as a percentage of the investment in the business. Also called *return on capital employed.* See **business bookkeeping; capital-equipment investment; cost; economic and product quality; invest early.**

revolutionary versus evolutionary developments Most new developments are evolutionary and evolve from an existing product. Even revolutionary developments usually involve certain existing fundamental or basic principles. Rarely revised, corrected, or new fundamental or basic theories evolve that produce genuinely revolutionary ideas. See **plastic history; productivity; research and development; technology.**

Reynold's number A dimensionless number that is significant in the design of any system in which the effect of viscosity is important in controlling the velocities or the flow pattern of a fluid. It is equal to the density of a fluid, times its velocity, times a characteristic length, divided by the fluid viscosity. This value or ratio is used to determine whether the flow of a fluid through a channel or passage, such as in a mold, is laminar (streamlined) or turbulent. The formula for Reynold's number is $R = 7{,}740\ VD/\eta$ or $3{,}160Q/D\eta$, where V = fluid velocity, in ft/s (m/s); D = diameter of circular passage in. (cm); η = kinematic viscosity, in centistokes; Q = flow rate in gpm. Water at the following °C temperatures are followed with η:0 = 1.79, 10 = 1.30, 20.2 = 1.00, 37.8 = 0.68, 66 = 0.43, and 100 = 0.28. Values of 2,100 or lower represent laminar flow and those above 3,000 represent turbulent flow. This flow information is used in designing fluid (water) lines in molds and rolls, where a certain degree of turbulence is required to remove heat from plastic melt most efficiently. Also called N_{re} or *Damkihler number V* (DaV). See **coolant; turbulent-flow; melt-flow laminar; mold coolings; scale; thermodynamics; viscosity; viscosity, Hagen-Poiseuille law; water, magnetic.**

RF heating See **heating, dielectric.**

R-glass See **fiberglass type.**

rheological material behavior All material behaviors range from fluids to fluids-solids to solids. As fluids they are purely viscous with linear behavior or Newtonian fluid, such as water or oil. The nonlinear or non-Newtonian purely viscous fluid (approaching fluid-solid conditions) is a suspension in a Newtonian fluid. Fluids-solids represent viscoelastic plastics, which are linear or nonlinear in fluid or solid forms. Elastomers or gums represent the purely elastic nonlinear solids, and their elastic linear or Hookean (law) solids are typically steel spring or cross-linked rubber. See **viscosity, Newtonian flow; viscosity, non-Newtonian flow.**

rheological mechanical spectrometer (RMS) A device that relates chemical structure of plastic to its mechanical properties. It measures viscous and elastic response in terms of dynamic viscosity over a wide temperature range (0 to 300°C) and mechanical frequency range.

rheology The science of the deformation and flow of matter under force. It is concerned with the response of plastics to mechanical force. The response may be irreversible flow or reversible flow. An understanding of rheology and the ability to measure rheological properties are necessary before viscous behavior can be controlled. Such control is essential for the manufacture and fabrication of numerous plastics materials and products. For linear elastic materials or Newtonian fluids, simple observations are sufficient to establish a general equation that describes how any material will respond to any type of deformation. However, for the more complex materials, such as non-Newtonian molten plastics, the development of a simple equation is complex and difficult to evaluate and requires many different test and evaluation studies. Relationships are developed and put to practical use. Present knowledge of their rheological behavior is largely empirical and useful for these viscoelastic plastics—that is, they exhibit both viscous flow and elastic recoil. See **deformation; melt flow; thixotropy; viscoelastic fluid; viscoelasticity; viscosity, Newtonian flow; viscosity, non-Newtonian flow.**

rheology, micro- The study of flow in relation to the microstructure of the material undergoing flow. An example is in the study of the effect of dispersed particle shape in a plastic blend or filled plastic on the flow properties.

rheometer A rheological instrument that determines the flow properties of a plastic, usually of high viscosity or in the molten condition of thermoplastics, by forcing the melt through a die or orifice of specific size at specific temperature and pressure. Also called *plastometer.* See **test, melt-index; viscometer.**

rheometer, Brabender plasticorder flow See **test, melt-flow, Brabender plasticorder rheometer.**

rheometer, capillary A rheometer whose main component is a capillary tube of specific diameter and length. Molten plastic at a specified temperature is forced by pressure through the tube. Differential pressures and flow rates are measured and used for analyzing shear stress against shear rate at a constant temperature. See **capillarity; viscometer, capillary**. An online capillary rheometer is a slit die or capillary die that is fed a controlled melt volume online from the extruder's plasticator. The pressure differential between start and the end of the tube is measured as a function of different flow volumes. The different shear stresses follow Hagen-Poiseuille law regarding the viscosity function. According to the law, the controlled melt flow through the capillary is directly proportional to the shear rate. The two basic online systems are the open- and closed-loop systems. In the open, there is a short distance of melt travel to obtain a sample; the closed loop has the melt recirculating after measurements are made into the main melt stream of the plasticator. See **viscosity, Hagen-Poiseuille law; test, melt rheometer.**

rheometer, dynamic A system in which the applied shear or tensile stress is varied periodically with time, usually sinusoidal. It is used to determine the dynamic and complex viscosities of fluids. Elastic modulus can also be determined. Also called *oscillating rheometer.* See **shear stress; tensile stress.**

rheopecticity Viscosity that increases with time under a constantly applied stress and decreases on removal of the stress. It is the opposite of thixotropy. See **thixotropy.**

rhombohedral See **directional property, rhombohedral.**

rib A reinforcement that is often used in fabricated products to increase rigidity. Various processing methods can provide a means of incorporating ribs.

rice paper See **fiber, straw.**

rigidity A combination of thickness and inherent stiffness of a material that resists flexing of the material. See **flexibility.**

rigidity, relative In dynamic mechanical measurements, the ratio of modulus at any temperature, frequency, or time to the specific modulus at the same conditions. See **dynamic mechanical measurement.**

rigidity, stiffness See **flexural strength; rigidity.**

rigidsol A plastisol that forms a product of very high durometer hardness. Such hardness is obtained by compounding techniques that permit the use of relatively small amounts of plasticizers or by the incorporation of monomers that serve as dilutents at room temperature but that will cross-link or polymerize on heating. See **hardness; plasticizer; plastisol; polymerization.**

ring gate See **mold gate.**

rise time See **reaction-injection molding rise time.**

risk, acceptable A level of risk that a seriously adverse result is highly unlikely to occur but that cannot be proven to be 100% safe. It is a reasonable assurance of safety and acceptable uncertainty as in the use of automobiles, aircraft, boats, lawnmowers, food, medicine, water, and the air we breathe. See **cost; design analysis; design technology; computer-aided; definition; legal matter: Insurance Risk Retention Act; people's challenge.**

Although the goal is to approach perfection in a zero-risk society, failure to recognize that no product is without risks may put excessive emphasis on achieving one goal while drawing precious resources away from product development and approval. A proper balance between risk and benefit acknowledges that people are exposed to many risks and that some pose a greater threat than others. The following data concern the probability over a lifetime of premature death per 100,000 people in the United States: 290 will die from being hit by a car while being a pedestrian, 200 from tobacco smoke, 75 from diagnostic X-rays, 75 while bicycling, 16 while passengers in a car, 7 from drinking Miami or New Orleans water, 3 from lightning, 3 from hurricanes, and 2 from fires. See **quality optimization goal; sampling acceptable quality level.**

risk, analyze See **economic efficiency and profitability.**

risk assessment An analysis of risk that needs to be performed by designers, equipment installers, users, and all others involved in production. The production process is reviewed for hazards created by each part of the line when operating correctly as well as when equipment fails to perform or complete its task. This includes startups and shutdowns, preventive maintenance, QC/inspection, and repair. See **statistical data collection.**

risk, fire The probability that a fire will occur and the potential for harm to life or damage to property resulting from its occurrence. A fire risks assessment standard can determine that no harm (or major harm) will occur.

risk management Risk management firms are liability insurance firms that sell forward contracts at fixed prices and then settle them against market prices established by various consultant firms. A cap is a typical method in which the risk-management firm reimburses the client (fabricator) if prices rise above a fixed, preagreed level. See **entrepreneur; legal matter: product liability; probability; sampling acceptable quality level.**

risk reliability See **control-system reliability; reliability.**

risk retention The client (fabricator) funds its own losses instead of paying a management firm. Some clients cannot afford insurance. See **legal matter: Insurance Risk Retention Act.**

Riteflex Hoechst-Celanese's tradename for its family of copolyester thermoplastic elastomers.

rivet, fabricating See **forging.**

riveting See **joining, rivet.**

robot A device that can perform discrete operations, such as parts removal, assembly, decoration, welding, inspection, stacking, wrapping, carton filing, palletizing, and lot identification. Sturdy/fast robots can be made from lightweight/high-strength materials such as carbon fiber/epoxy-reinforced plastics that accelerate to at least 25 Gs and attain linear velocities of at least 60 ft (18 m)/sec, all of which permit part retrieval in as little as 300 milliseconds. Their arms can retrieve parts in a definite orientation as fast or faster than they can fall free by gravity. See **design, motion-control, mechanical and electronic effects; material handling, automatic; mold change, quick; part handling.**

robot, intelligent A robot that has sensory perception, making it capable of performing complex tasks, such as those that vary from cycle to cycle. It is capable of making decisions and modifications during each cycle. See **sensor, intelligent.**

robot, material-handling A robot that can machine, cut, form, decorate, weld, or in some way change the shape, function, or the properties of the materials it handles between the time they are first grasped and the time they are released in a manufacturing line. See **auxiliary equipment; material handling; part handling.**

robot, mobile A robot that is mounted on a moving platform in the plant. The control system controls the motions of the robot about the workplace.

robot, pick and place A popular, simple, point-to-point, nonservo, limited-sequence robot designee that primarily manipulates products from one place to another.

rock-and-roll processing See **molding, rock-and-roll.**

rocket and missile See **missile.**

Rockwell hardness See **test, Rockwell hardness.**
rodent-resistant additive A substance that allows a plastic to withstand or repel attacks by rodents. Some plastics require these additives to prevent rodents from damaging them, such as under- and over-the-ground cable insulations.
rod stock Unreinforced plastic or fiber reinforced plastic lay-up that is combined to give the greatest strength in the longitudinal direction. The RPs are generally formed from parallel strands or fibers. See **extruder profile; reinforced-plastic pultrusion.**
roentgen spectrometry See **x-ray spectroscopy.**
roll Rolls handle fabrication products, such as films, sheets, fibers, and coating lines. They include winders, dancer rolls, spreader rolls, tenter rolls, textured rolls, engraved rolls, and cooling rolls. They are required to be extremely precise in all their measurements, surface conditions (including commercial-grade mirror finishes), center-line operations, bearings, and rotating speed. See **calender; calendering, control nip pressure; coating; embossing; extruder roll; machining; tolerance, full-indicator-movement.**
roll arbor A shaft or spindle over which is placed a core or tube on which products such as film or sheet is wound that can be used directly at the end of production lines. Also called *mandrel.*
roll, bowed See **extruder-roll spreader or expander.**
roll coating The process of coating substrates (web) with plastics in the form of liquids, solution, or dispersions by contacting the substrate with a roller on which the material is spread. Various designs meet the different requirements of the material to be processed and the form or shape of the substrate to be coated. There are direct or forward roll coaters (roll and web travel in the same direction), reverse roll coaters (used with highly viscous plastic, with the roll and web traveling in opposite direction), three-roll nip-fed reverse coaters (coating is wiped off the roll onto the web and no splits or kiss marks develop on the coating), and others. See **calendering configuration, roll; coating; coating, curtain.**
roll coating, kiss See **extruder coating and laminating; extruder roll coating, kiss.**
roll cooling See **coolant; extruder roll cooling.**
roll covering The application of elastomers to the surface of mandrels. Covered rolls are used in a variety of industries that include plastic fabrication, printing, paper, and textile. They are used to squeeze, drive, pull, emboss, convey coat, reduce noise, and print. The diversity of industries has slowed the evolution toward automation. A complete roll covering company may work as many as 200 different compounding formulations with relatively few orders per compound. Fabricating processes include calendered sheets (full sheet or strip), machined strip building, precured tubing, and multipass flat-50% overlap.
roll, dancer See **extruder roll, dancer.**
roller, pinch-draw A puller unit where rollers are used as for pull film or coating in an extrusion, coating, and other processing lines.
roll leaf stamping See **printing, roll-leaf.**
roll nip See **calendering, controlled nip pressure; nip.**
roll, pinch draw A set of rollers that are used as downstream pullers of the product that is being processed.
roll plating See **chrome plating.**
roll, preheater See **extruder roll preheater.**
roll pressure A roll used to apply pressure to consolidate plastic to the substrate or laminate plastic, such as film, sheet, or profile. See **calendering pressure force; coating, roller; coating, spread; extruder roll; laminate; pressure-detecting film; reinforced plastic pultrusion.**
roll printing See **printing, gravure.**
roll, reverse See **coating, reverse-roll.**
roll slippage See **extruder-web tension control, slipping and tearing.**
roll, spreader/expander See **extruder roll spreader or expander.**
roll stand For a sheet extrusion line with usually three rolls, calendering with two to seven, and other lines, a device that provides thickness control, surface with a smooth to textured finish, laminating, and line-speed control. These stands are made with rolls that have precision tight tolerances and that provide uniform surface temperatures, spacing, and rpm. To meet different plastic-material performance requirements, the stands can be in different positions, such as the popular vertical, at any angle, L-position, with downstack (material travel downward) or upstream. See **calender; extruder sheet.**
roll steel, etching See **photoetching tool.**
roll stretching See **extruder-web stretching and tearing; orientation, tenter frame and roll.**
roll, tension control See **extruder roll tension control; tensile strength.**
roll, winding strain See **extruder roll winding strain.**
roll texturing See **embossing.**
roll tolerance See **tolerance, full-indicator-movement.**
roll, winding chuck See **extruder-roll winding chuck.**
roll, winding strain See **extruder-roll winding strain; strain.**
Roman geomembrane See **geomembrane.**
roofing See **bitumen; plastic house.**
root-mean-square See **deviation, root-mean-square.**
root-mean-square, electrical See **electrical root-mean-square voltage.**
root-mean-square voltage See **deviation, root-mean-square voltage.**
Rosato Surname of the persons who created this encyclopedia. **1.** Dominick V. (60+ years plastics industry experience); Marlene G. (30+ years experience); and Donald V. (40+ years experience) are the main contributors to this 17th major Rosato plastics book. **2.** Extended first name derivatives currently include Mafalda, Virginia, David, Andrea, Peter, Andrew, and Matthew. **3.** An inclusive

term encompassing all the extended past, present and future plastics and related friends (i.e., Goslings) to whom this book is dedicated. See 25,000 entries of this *Concise Encyclopedia of Plastics*.

rosin A plastic that is obtained as a residue in the distillation of crude turpentine from the sap of the pine tree (gum rosin) or from an extract of the stumps and other parts of the tree (wood rosin). It is used in the formulation of certain surface coatings. Also called *colophony*. See **coating.**

rotary molding See **clamping platen, rotary.**

rotational molding A process that is based on the heating and cooling of an axially or biaxially rotating split hollow-cavity mold that defines the outside shape of the required product. No pressure is applied other than the relatively low-contact pressure developed during rotation of the heated melt. The most common is the multiarm turret machine, which has a three-stage operation: (1) an oven heated by air (usually gas fired) or by a liquid of high specific heat (such as molten salt where a jacketed mold is used) or by a hot liquid medium such as oil, (2) a separate cooling chamber (usually water spray), and (3) a turret with a moving arm that moves a single or multicavity mold through the process. A premeasured amount of powder or liquid thermoplastic material is placed in the cavity, which is mounted on a turret arm that is capable of rotating the mold. This action permits uniform distribution of the plastics by forcing it against the inside surface of the cavity. Following a prescribed cycle, the heat of the oven fuses or sinters the plastic, which then goes into the cooling chamber. The solidified product is removed from the mold, and the cycle is repeated. This process permits the molding of very small to very large products. To improve product properties, hasten product densification, reduce air voids, or reduce cure time, the vacuum should be placed in the closed mold rather than venting the mold to the outside atmosphere. Also called *rotomolding, rotational casting, centrifugal casting*, or *corotational molding*. See **casting, centrifugal; casting, slush-molding; material pulverizing; powder coating; powder molding; salt bath.**

rotational molding cycle The cycle times typically range from 6 to 12 minutes. They can be as little as about 5 minutes or as long as 30 minutes for large parts. The wall thickness of the parts affects cycle times but not in a direct ratio. For example, with polyethylene plastic the cycle time increases by about 30 s for every 25 mils of added thickness up to $^1/_4$ in. thickness. Beyond $^1/_4$ in. the heat-insulating effect of the walls increases cycle times disproportionally for any further increase in thickness; cycle times usually have to be determined experimentally or can be based on prior experience. See **cycle.**

rotational molding load See **material charge.**

rotational molding lockout See **safety, machine-lockout.**

rotational molding mold See **molding, open-mold.**

rotational molding operator's sequence See **operation, automatic; operation, manual; operation, semiautomatic.**

rotational-molding product Products such as fuel tanks, furniture, light shades, marine accessories, material handling bins, shipping drums, storage tanks and receptacles, surf boards, and toys. Sizes range from small balls to at least 22,000 gallon tanks (83 m^3) that weigh at least $2^1/_2$ tons (5,500 lb).

rotational molding, reinforced See **reinforced plastic rotational molding.**

rotational molding, rock-and-roll See **molding, rock-and-roll.**

rotational molding, soluble core See **eutectic mixture; soluble core molding.**

rotational molding speed The mold in the oven spins biaxially with rotational speeds being infinitely variable, usually ranging up to 40 rpm on the minor axes and 12 rpm on the major axes. A 4:1 rotational ratio generally is used for symmetrically shaped parts. A wide variety of ratios are necessary for molding unusual and complex shapes.

rotational molding type The two basic types are batch and carousel. The batch type is manually operated and goes into an oven followed by the cooling station. The most common is the carousel type, with three stations of heating, cooling, and part removal followed by reloading the plastic material. Three cantilever arms 120° apart are used on a central turret so that as one arm with a mold leaves a station, another follows into that station. All operations are automatic. Four-arm machines can provide a second oven, cooler, or load station, depending on which is the most time consuming so that the cycle time can be reduced. See **clamping platen, rotary.**

rotational molding venting Venting often is used to maintain atmospheric pressure inside the closed mold during the entire molding cycle. A vent reduces flash, prevents mold distortion, and lowers the pressure needed in the mold to keep the mold closed. It prevents blowouts caused by pressure and permits the use of thinner molds. The vent can be a thin-walled plastic tube of PTFE that extends to near the center of the cavity. It enters the mold at a point where the opening it leaves will not affect the part's appearance. The vent can be filled with glass wool to keep the powder charge from entering the vent during rotation. See **venting.**

rotational rheometer See **test, melt-flow.**

rotational welding See **welding, spin.**

rotation, speed See **stroboscope.**

rotate mold See **blow molding, injection-with-rotation.**

rotogravure printer See **printing, gravure.**

rouge See **pigment, rouge.**

roughness Relatively finely spaced surface irregularities where height, width, and direction establish a definite surface pattern.

round See **out-of-round.**

roving A collection of bundles of continuous filaments or fibers, usually glass fibers, either untwisted strands or twisted yarns. Rovings can be lightly twisted; their degree of twisting and format depends on their use. For example, for filament winding they are generally wound as bands or tapes with as little twist as possible. See **fiber processing; preform process, plenum chamber; reinforced plastic.**

roving ball The supply package that is offered to the filament winder (and others) and that consists of a number of ends or strands wound onto a length of cardboard tube to a given outside diameter. Usually it is designated by either fiber weight or length in yards. *Spool* is sometimes used to identify the roving ball, however, the preferred term is *roving ball.*

roving ball doff See **material doff.**

roving band A collection of strands or ends that act together as a band or ribbon.

roving catenary A measure of the difference in length of the strands in a specified length of roving, which is caused by unequal tension. It is the tendency with some strands in a taut, horizontal roving to sag more than others, which in turn can effect the properties of the fabricated part.

roving cloth A coarse textile fabric woven from rovings.

roving, collimated A roving that is made using a process permitting parallel winding so that the strands are more parallel than in standard roving.

roving cord See **asbestos roving; cordage.**

roving end A strand of roving consisting of a given number of filaments gathered together.

roving end count An exact number of ends supplied on a ball or roving. See **fiber end.**

roving fiber tension, even A process whereby each end of roving is kept in the same degree of tension as the other ends making up a ball of roving. See **roving catenary.**

roving fuzz A measure of broken filaments in a strand or roving.

roving integrity The degree of bond between strands in a roving.

roving knuckle The point at the end of a way-wound roving ball where the roving reverses its axial direction.

roving open-top package A term used to describe a roving package in a carton that has no top.

roving ribbonization A phenomenon occurring in a finished roving on which the individual strands have been "blocked" or bonded together to give a ribbon of strands. It describes the degree of bonding together of the strands of roving that make up the roving band.

roving, spun A heavy low-cost glass or aramid fiber strand consisting of filaments that are continuous but doubled back on themselves.

roving strand count See **fiber count; filament strand.**

roving, textile A form of fibrous glass having less twist than is present in a yarn. As a fibrous glass reinforcement, it means strands of continuous fibers wound into a cylindrical spool. Usually 60 strands or ends are used. For staple fibers, roving is used to designate one or more slivers with a very small amount of twist and thus indicates an intermediate stage between sliver and yarn.

roving tow See **fiber tow.**

roving twist See **yarn twist, direction of.**

RTD See **temperature sensor.**

RTV silicone See **adhesive, room-temperature cure.**

rubber **1.** A cross-linked polymer having glass transition temperatures below room temperature that exhibits highly elastic deformation and have high elongation. See **glass transition temperature; mastication; vulcanization.** **2.** A material that is capable of recovering from large deformations quickly and forcibly. A rubber in its modified state, free of diluent, is identified by different tests. For example, it retracts within 1 minute to less than 1.5 times its original length after being stretched at room temperature to twice its length and held for 1 minute before release. It can be, or already is, modified to a state in which it is essentially insoluble (but can swell) in a boiling solvent, such as benzene or methyl ethyl ketone. Also called *elastomer, natural rubber, thermoset elastomer, thermoset rubber,* or *synthetic rubber.* See **elastomer; rubber, natural; rubber, synthetic.**

rubber, camelback See **rubber tire, camelback.**

rubber elasticity The elastic behavior of plastics is well above their glass transition temperature (the rubbery region of viscoelasticity behavior), where they show elasticity at high strains of up to several hundred percent. If the material is perfectly elastic, then all the work done will be stored as strain energy. A highly successful statistical molecular theory of rubber elasticity has been developed that closely describes many of the experimentally determined features of elastomer behavior. See **polymer network.**

rubber green strength See **tensile green strength.**

rubber heat test See **test, Wiegand pendulum heat.**

rubber hydrochloride plastic A nonflammable thermoplastic that is obtained by treating a solution of natural rubber with anhydrous hydrogen chloride under pressure at low temperatures. The packaging film Pliofilm is an example.

rubberize To impregnate or coat a substrate with rubber. See **coating; impregnation.**

rubber latex See **electrophresis; latex, natural rubber.**

rubber latex, agglomerate A cluster of rubber particles in a colloidal aqueous suspension that are reversibly or irreversibly joined together to form latex particles.

rubber latex, natural See **latex, natural rubber.**

rubber market Worldwide demand for rubber will grow at a faster rate than the major market (tires) supply because of the large gains expected in nontire rubber demand, especially in newly industrialized countries. Of the total market, 66wt% is synthetic and 34% natural; 40% is in tires and 60% nontire. The United States consumes 19%, the most of any one country.

rubber, natural (NR) The commercial base for natural rubber is latex, a milklike serum produced from the *Hevea brasiliensis* tropical tree, originally existing only in the South American Amazon River basin. Charles de la Condamine described this material to the French Academy (1736). The derivation of the word *rubber* is attributed to John Priestley, an English chemist who discovered oxygen in 1774 and used rubber for rubbing out unwanted pencil marks. Charles Goodyear extensively used it even prior to the discovery of vulcanization (thermoset cross-link curing with sulfur) in 1836. Many grades and types of NR are available with varying impurity levels, filler additives, and processing methods. NR has a great capacity for being deformed. Its advantages include high resilience and elasticity, cut and abrasion resistance, and general endurance. Service temperature is from −50° to 120°C (−58° to 248° F). Its poor oil, oxidation, and ozone resistance can be minimized by proper design and compounding ingredients. Many synthetic elastomer or rubber plastics have been developed. The literature abounds with descriptions of these traditional thermoset elastomers. Its molecular structures determine its stress-strain ratio, viscoelasticity, and fatigue properties as they relate to the effects of the environment. See **antioxidant agent; barrel history; elastomer; filler; latex; latex; natural rubber; masticate; molecular-arrangement structure; molecular weight; plastic, natural; rubber, synthetic; viscoelasticity; vulcanization.**

rubber pad forming See **forming, rubber pad.**

rubber peptizer See **latex, natural rubber; peptizer.**

rubber/plastic See **chloroprene plastic.**

rubber processing Many of the techniques used for processing plastics are modifications of those developed originally for processing rubber. Natural rubber undergoes the following basic steps to become a useful product: rubber trees; latex (strained); pale crepe, smoked sheet; bales; dispatch to a rubber factory; bale cutting and blending; mastication (peptizers) or mixing (banbury or two-roll mill) where compounding occurs (accelerators, activators, antioxidants, fillers, pigments, vulcanizers, etc.); maturing; remilling (calendering, compression, extrusion); curing; cutting and machining; finished product. See **fabricating process type; tensile green strength.**

rubber, raw Natural or synthetic rubber (elastomer) that is in bales or packages that are the starting material for the manufacture of rubber (elastomer) products.

rubber scorch See **vulcanization scorch.**

rubber solvent See **carbon disulfide.**

rubber stretching See **heat effect, Gough-Joule.**

rubber, synthetic Where natural rubber is thermoset material, synthetic rubbers are available as thermoset and thermoplastic materials. Their compounding basically is the same as natural rubbers, but they are in a class of their own. See **butadiene rubber; polyisobutylene butyl rubber; thermoplastic; thermoset plastic.**

rubber, thermoplastic or thermoset See **thermoplastic; thermoplastic elastomer; thermoset elastomer; thermoset plastic.**

rubber tire, camelback Tread-type rubber compound extruded in a variety of thickness and widths for use in tire retreading. The name is derived from the shape of the section that resembles the hump of a camel. This term has replaced *tread rubber*, which in certain contexts can be ambiguous. See **weftless.**

rubber transition See **glass transition.**

rubbery material Rubber (natural or synthetic), elastomer, elastomer/plastic, and plastic/rubber materials. See **elastomer; rubber.**

rubbery plateau For a plastic, the range of temperatures between the glass transition and melting temperatures that has a viscoelastic modulus that is relatively constant. See **elasticity; glass transition temperature; melt temperature; modulus; viscoelasticity.**

rubbish See **waste.**

run The dripping or sagging of a material such as an extrudate, ink, and paint. It is usually caused by too much material, poor processing conditions, or too much heat. See **defect.**

runnerless injection molding See **mold, runnerless.**

runout **1.** The absence of a failure at a specified number of cycles. **2.** In a linear stage, any unwanted motion other than pure translation. Thus, runout may include yaw, pitch, and roll during processing. See **concentricity; full indicator movement; mathematical closure error; tolerance, full indicator movement.**

rupture A break or cleavage that results from physical stress. Work of rupture is the integral of the stress-strain curve between the origin and the point of rupture. See **shear failure; stress-strain curve; tensile strain rupture.**

rupture disc See **plasticator safety.**

rupture envelope See **Mohr envelope.**

rupture strength The true value of rupture strength is the stress of a material at failure based on the rupture's cross-sectional area. See **creep rupture strength; strength; stress; tensile strength.**

rupture time The time that is required to rupture a specimen or part under constant stress and temperature in a creep test.

rupture work The work of rupture is the integral of the stress-strain curve between the origin and the point of rupture. Its dimension is in energy-volume^{-1}.

rust The reddish corrosion product formed by electrochemical interaction between iron and the atmospheric oxygen. See **cavitation erosion; erosion.**

R-value See **insulation R-value, heat.**

Rynite DuPont's trade name for its family of glass-fiber-reinforced plastics.

Ryton Phillips Petroleum's trade name for its family of polyphenylene sulfide plastics.

S

sabin unit See **sound absorption.**
sack See **packaging, grocery-bag.**
sacrificial ply See **reinforced-plastic peel ply.**
safe, generally GRAS—generally recognized as safe. See **risk, acceptable.**
safety Safety information and standards for products and processing equipment are available from various sources, including equipment suppliers, the Society of the Plastics Industry, and the American National Standards Institute (ANSI). Equipment manufacturers and fabricating plants have continuously upgraded safety. For example, safety interlocks ensure that equipment will not operate until certain precautions have been taken. Safety machine lockout procedures establish proper lockout procedures for electrical and mechanical circuits. There are preloaded pressure bolts around dies, pressure rupture disks on barrels, turret winder emergency stops, coextrusion line alarms if one extruder stops, drop bars between platens (IMM, CMM, etc.), and so on. The operating environment is continuously upgraded with reduced sound and noise in the operating areas. See **electrical power disturbance; ISO-10993 certification; legal matter: accident reporting; pipe, water deterioration; plant safety; plastic feed form; quality; rail track protection; design safety factor; training; Underwriters' Laboratory Standard UL-544.**
safety and chemical surface treatment See **fluorination; gasoline tanks; sulfonation; surface treatment.**
safety and design See **design safety factor.**
safety and electric power See **electronic standard, international.**
safety and electromagnetic interference See **electromagnetic compatibility; electromagnetic interference.**
safety and flammability See **fire; flammability.**
safety and machines To protect operating personnel from recognized hazards, the American National Standards Institute (ANSI) provides voluntary standards to assign responsibilities to machine manufacturers, remanufacturers, modifiers, and employers to ensure that safety measures are taken. They are updated periodically. In 1992 the U.S. Occupation Safety and Health Administration adopted these standards and made them mandatory; D.V. Rosato pioneered SPI involvement from the mid 1970s in this important task. Revisions and updates are made regularly. See **clamping preclose.**
safety, police-officer Police officers wear protective vests that are made from specially designed nylon (aramid) fibers. See **fiber, nylon.**
safety and product liability See **design and product liability; legal matter: product liability law.**
safety and processing Processing equipment procedures outline operating and safety requirements. Checklists include preparation (moving material, etc.), startup and shutdown procedures, tooling changes, and cleanup. Most equipment generates high heats and pressures. Equipment is built to run safely but must be treated with respect. With plastics that decompose, there may be hazards such as burns and wounds, air contamination, and potentially major problems with equipment. Faulty controllers or freeze-off can cause the overheating situation due to a burned-out heater. See **chemical safety and processing.**
safety assurance See **risk, acceptable.**
safety, barrel See **barrel fail-safe rupture disc; barrel-venting safety; plasticator safety.**
safety bar, roll nip See **calendering safety.**
safety block Any type of spacer or device in any machine that prevents movement of a member under its own weight or by actuating the normal movement control.
safety, bolt preload An extruder die attachment has preloaded bolts or shear pins.
safety, consumer See **legal matter: Consumer Product Safety Act.**
safety crisis See **training crisis.**
safety, decontamination See **radioactive decontamination.**
safety device All machines are equipped (or should be equipped) with applicable electrical, hydraulic, or mechanical safety devices. Some of them, such as injection-molding machines, have all three modes of safety devices.
safety, electrical equipment See **electronic standard, international.**
safety emergency stop device An emergency stop device can operate mechanically (trip rod, button, cord, drop bar, etc.), hydraulically, optically, or electrically/electronically. It is a system that when activated will immediately stop the operation of the machine without contact or injury of people and products.
safety, engineering The application of established standard engineering principles to all facets of plant safety by professionally trained personnel. See **design, engineering.**
safety extruder See **extruder pressure-head safety; extruder take-off winder emergency stop.**
safety factor, design See **design-failure theory; design safety factor; factor of ignorance; statistical material selection, reliability.**
safety, fire and flammability See **burned; burning rate; fire retardant; flash; fume; heating, catalytic; incineration; limiting index oxygen; smoke emission.**
safety gate and screen guard The movable barriers that allow the operator of equipment access to the fabricat-

ing area, such as the mold or die, with safety. When these barriers are moved or removed, the equipment will not operate until they return the equipment's operating mode. Mechanical, electrical, or hydraulic devices are used to interrupt operating circuits when these barriers are opened. See **injection-molding machine safety gate.**

safety glass Shatterproof glass is a composite or laminate consisting of two or more sheets of plate glass (usually tempered glass in flat or curved form) with an interlayer of polyvinyl butyral plastic that is 0.20 to 0.40 in. (0.05 to 1.0 cm) thick between each adjoining glass plate. The plastic is bonded, via an air evacuated restricted heating system, to the glass and virtually eliminates the shattering of the glass on impact (rocket, bullet, etc.). This composite has been used in automobile windows since the 1930s. Future windows may be all plastic (PC, etc.). See **impact resistance; polyvinyl butyral plastic.**

safety hardener A curing agent that causes only a minimum of toxic effect on the human body and that meets government regulations, either on contact with the skin or as concentrated vapor in the air. See **hardener.**

safety helmet Various types of helmets (football, bicycle, etc.) use plastics that range from rigid to flexible types of thermoplastics to thermoset reinforced plastics. The first of the so-called modern safety helmets was designed during 1944 in the Materials Laboratory (DVR) of Wright Patterson AFB, Dayton OH. See **cellulose ethyl plastic; foam; reinforced plastic.**

safety insurance See **legal matter: Insurance Risk Retention Act; risk, acceptable.**

safety interlock A safety device that is designed to ensure that a piece of equipment will not operate until certain precautions have been taken. See **programmable-controller safety.**

safety, machine-lockout Proper locking out of, for example, a machine's electrical circuit before starting repairs protects the maintenance worker from accidental startups that could cause severe injury. The National Safety Council offers the following steps for proper lockout of a machine's operation (such as its electrical, hydraulic, or mechanical circuits) (1) shut down all possible switches at the point of operation, and then open the main disconnect switch, (2) snap a lock on the main disconnect switch box, such as a padlock, that has only one key, (3) check the lockout device and safety interlock to make sure the switch cannot be operated, (4) place a name tag on the shank of the lock to indicate that the machine has been locked out, (5) notify the supervisor when repair work has been completed so that the removal of the lock can be made, and (6) take off the name tag and remove the lock. See **fabricating process type.**

safety manuals and standards The SPI and ANSI are major providers of safety information on many different aspects of plant operation, including material handling, material storage, and the different upstream and downstream equipment.

safety mechanism A device that is intended to prevent accidental actuation of tool, from hand held to highly sophisticated tools.

safety medical standard See **electronic standard, international.**

safety, runway See **foamed ground aircraft arrester.**

safety rupture disc See **barrel fail-safe rupture disc; plasticator safety.**

safety standard See **Underwriters' Laboratory Standard UL-544.**

safety stop bar In presses with a movable platen (injection, blow, compression, laminating, etc.), a mechanical safety drop bar or its equivalent is used so that platens will not move and remain in the open position until the machine is ready to operate.

safety turret emergency stop See **extruder take-off winder emergency stop.**

safety, underground pipe See **pipe, deteriorating; sewer rehabilitation.**

safety, vented barrel See **barrel-venting safety.**

sag When heat or pressure is applied to plastic, it may be desirable or undesirable to cause the plastic to sag (droop, sink, settle, etc.). Certain fabricating processes require control of sagging. See **blow molding, extruder, parison sag; thermoforming sag; thickening agent.**

sales See **cost; government contract directory; legal matter; production data acquisition; wholesaler.**

sales and marketing See **market; World of Plastics Reviews: Making Marketing Work.**

sales investment turn The measurement of a business cycle. Investment turns are usually measured in terms of how many times the investment is turned over in the annual volume of sales. Thus, investment turn equals sales divided by investment capital. See **business; capital equipment investment; cost; economical control of equipment; gross domestic product; invest early; profitability study; project checklist; return on investment; risk, acceptable.**

sales, machinery See **plastic-industry machine sales.**

sales, percent method An analysis of historic income statement expense items as they relate to net sales. The percentages derived are the bases for projecting future expenses once future sales have been forecasted. See **manufactured cost.**

sales projection See **economic efficiency and profitability.**

salt The material that is formed as a result of the reaction of acids and alkalies. It is used in the production of certain plastics and as an additive in compounds. Common salt, sodium chloride, occurs in nature principally on the ocean floor.

salt bath A molten mixture of sodium, potassium, barium, and calcium chlorides or nitrates, to which sodium carbonate and sodium cyanide are sometimes added. It is used to provide a heat "bath" for plastics when uniform heat is required, such as during certain polymerization reactions, curing, heat treatment, and annealing. Examples of products include certain wire and cable insulation extrusion lines and contact or low-pressure curing of thermoset plastic-reinforced plastics. See **extruder wire and cable; fluid-bed process; rotational molding.**

salt cleaning See **cleaning, hot-salt.**

salt hydrolysis The reaction of the anion or cation of a salt with water.

salt, soluble See **solubility product.**

sample The portion or unit that represents a lot that is intended to be representative of the whole.

sample, standard See **deviation, standard of sample.**

sampling Obtaining a representative portion of the material or product concerned. The number of samples that are required for each test is specified to obtain a reasonably reliable test value. Information on variation test values, sample-to-sample, and other sampling procedures is presented in ASTM D 2188. See **design allowable; quality control; statistic.**

sampling acceptable quality level (AQL) The maximum percent of defective units or the maximum number of defects per hundred units that, for purposes of sampling inspection, can be considered satisfactory as a process average. The phrase "can be considered satisfactory" is interpreted as a producer's. When the standard is used for a percent defective plan, the AQLs are possible from 0.010 to 10.0%. For defective-per-unit plans, there are additional AQLs, so AQLs are possible from 0.010 defect per 100 units to 1,000 defects per 100 units. The AQLs are in a geometric progression, each being approximately 1.585 times the preceding one. AQLs are determined from (1) historical data, (2) empirical judgment, (3) engineering information (such as function, safety, interchangeable manufacturing, etc.), and (4) experimentation. The AQL is the most important part of the sampling standard (ISO-2859) because the AQL and the sample size code letter index define the sampling plan. See **quality level, acceptable; reliability; risk, acceptable.**

sampling plan An acceptance sampling plan for lot-to-lot inspection by attributes was first devised in 1942 by a group of engineers at Bell Telephone Laboratories. It was designated initially as JAN-STD 105; later MIL-STD 105. In 1973 it was adopted by the ISO and designated ISO-2859. It has become the standard for attribute inspection for all industries. Its applicability includes (1) end use items, (2) components and raw materials, (3) operations, (4) materials in process, (5) supplies in storage, (6) maintenance operations, (7) data or records, and (8) administrative procedures. The standard provides for three types of sampling—single, double, or multiple. Defects are classified as critical defects and may contain major or minor defects. See **inspection; quality control; specification; standard; storage.**

sampling size The sample size is determined by the lot size and the inspection level per sampling plan (just reviewed). The inspection level to be used for a particular requirement will be prescribed by the responsible authority. The decision on the inspection level is also a function of the type of product. For inexpensive products, for descriptive testing, or for harmful testing, different inspection levels are considered.

sampling statistically See **statistical benefit.**

sandarac A natural plastic obtained from the North African *Callitris quadrivalvis* and used in varnishes and lacquers.

sand blast A surface treatment in which sand materials are blown on the surface to produce a roughened surface. See **surface treatment; texturizing.**

sand casting See **foundry plastic; foundry shell molding.**

sanding A finishing process that uses abrasive belts and disks. It sometimes is used on parts to remove flash, particularly thick flash on thermoset plastics. See **ashing; finishing, ashing and lapping; grinding; machining; molding flash line; plating; polish; surface finish.**

sand, quartz See **fluid-bed process.**

sandwich construction A structure consisting of relatively dense, thin, high-strength facings that are bonded to a less dense, low strength intermediate material or core (plastic foam, honeycomb, etc.). See **coextrusion foam core; core; design, EI theory; design, sandwich-construction; injection molding, sandwich; moment of inertia; plastic house.**

sandwich core material The primary function of a core is that of stabilizing the sandwich facings and carrying most of the shear loads through its thickness. To perform this task efficiently, the core must be as rigid and as light as possible, deliver uniformly predictable properties in the environment, and meet performance requirements. There are different shapes or styles of cores, such as the popular honeycomb (plastic fabric or film, aluminum foil, etc.), fluted core (an integrally woven reinforcement material consisting of ribs between two skins for unitized construction), plastic and metal foam, and balsa wood. See **coinjection molding; core; core, honeycomb or foam; foam; foamed polyurethane; injection molding, sandwich; shear strength; wood, balsa.**

sandwich facing material The primary function of the face sheets is to provide the required bending and in-plane shear stiffness and to carry the axial, bending, and in-plane shear loading. In high-performance structures the facings that are most commonly chosen are reinforced plastics, aluminium alloys, titanium, or stainless steel. Even the most economical of these products represents a substantial cost, and customary practice is to choose among them very carefully on a value engineering approach or on the lowest-lifetime-cost basis. When choosing facing material, as well as the core, adhesive for bonding faces to core, or other materials (inserts, etc.), it is wise to examine the less obvious properties of the material, such as toughness or brittleness, durability and weatherability, compatibility with rivets and bolts, and other such attributes that may directly affect the usability or success of the end product, even though they are not directly involved in stress analysis or weight savings. See **value analysis.**

sandwich peel torque With sandwich panels, the facings should not pull away from the core material because it reduces the strength of the panel. An example of a test is a rolling-climbing drum wheel that measures the torque required to peel facings from its core. See **adhesive peel strength; reinforced plastic peel ply.**

sanitize To make sanitary, such as by cleaning and sterilizing. See **cleaning; sterilization.**

sanitizer agent See **odorant agent.**

sapphire fiber See **fiber, ceramic.**

Saran Dow chemical's trade name for its polyvinylidene chloride plastic.

satin finish See **fiber finish, satin.**

satinizing In adhesive and solvent bonding, a chemical etching process in which a mildly acidic solution is used to produce uniform anchor points on a part surface. Finishes, cements, or adhesives then bond to the anchor points, resulting in a strong adhesion. The process was developed by DuPont for its Delrin acetal. See **surface treatment.**

satin weave See **fabric, satin.**

saturation **1.** The coexistence in stable equilibrium of a vapor and a liquid or a vapor and solid phase of the same substance at the same temperature; the state of solution holding the maximum possible quantity of dissolved matter at a given temperature. See **chemical saturation; unsaturation; water of saturation; water saturation. 2.** The state in which all available valence bonds of an atom (particularly carbon) are attached to other atoms. **3.** In color, the dimension of color that describes its purity. If highly saturated, it appears to be a pure hue and free of gray; if of low saturation, it appears to have a great deal of gray mixed with it. See **hue. 4.** An attribute of a visual sensation according to which an area appears to exhibit more or less chromatic color, judged in proportion to its lightness or brightness. See **colorant. 5.** See **plasticizer, iodine value.**

saturation, chemical See **chemical saturation.**

saturation compound An organic compound that does not contain double or triple bonds and thus cannot add on elements or compounds.

saturation, degree of The ratio of the weight of water vapor that is associated with a pound of dry air to the weight of water vapor that in associated with a pound of saturated air at the same temperature.

saturation pressure The pressure, for a pure substance at any given temperature, at which vapor and liquid, or vapor and solid coexist in stable equilibrium.

saturation, super- The condition in which a solvent contains more dissolved matter (solute) than is present in a saturated solution of the same components at equivalent temperature. It is most commonly achieved by supercooling. See **cooling, super-.**

saturation, wet strength An equilibrium condition in which the net rate of absorption under prescribed conditions falls essentially to zero. See **strength, wet.**

saw Although a saw can handle fewer cuts per minute than other cutting methods and produces dust and a ragged cut, it still provides a practical way to handle certain products, such as very large, thick parts, large-diameter pipe or profiles, and short-run production orders. See **cutter; kerf; machining.**

sawdust An organic cellulosic filler. See **filler.**

S-basis A property that is the minimum value specified by the appropriate specification for a material. See **A-basis; B-basis; population confidence interval; typical basis.**

scale **1.** A condition in which unwanted plastic plates or particles are on the surface of a part, such as reinforced plastic. They can usually be removed but sometimes leave surfaces with voids or depressions. See **defect. 2.** A calcareous deposit in water tubes or lines that results from the deposition of mineral compounds that are present in water. When scale forms in mold cooling lines, poorer heat transfer causes longer cooling cycles that increase costs or create inferior molded products. See **mold cooling; Reynolds number; water, magnetic; water softening. 3.** Surface area of oxidized metal. See **corrosion. 4.** Scaling, also called *flaking*, is the process of removing scale with or without acid fumes, sometimes referred to as *spontaneous detachment of scale.*

scale-up The planning involved in carrying out a complete or part of a processing operation from pilot plant to large-scale production. See **fabricating process; product scale-up.**

scarfing See **flash scarfing.**

scarf joint See **joining, scarf.**

scatter See **coefficient of scatter.**

scattering See **light scattering; x-ray diffraction.**

scavenger A substance added to a mixture or compound to consume or inactivate traces of impurities. See **contamination; packaging, oxygen scavenger food.**

schedule See **production schedule.**

schlieren See **test, nondestructive transparent medium light schlieren.**

science See **art and science; computer science and algebra; design theory and strength of material; experience and science; plastic and the future; productivity; technology.**

scientific method The systematic collection and classification of data and, usually, the formulation and testing of hypotheses based on the data. See **art and science; computer-aided; graphic art; productivity.**

scission See **degradation, scission.**

Scleroscope hardness See **test, Scleroscope hardness.**

scorch Premature vulcanization of a rubber or thermoset elastomer. See **vulcanization scorch.**

scorch, Mooney See **injection-molding melt-flow oscillation; test, scorch Mooney.**

Scorim process See **injection-molding melt-flow oscillation.**
scouring A wet process of cleaning by chemical or mechanical methods. See **cleaning.**
scrap **1.** Any part of a product that is not part of the finished product, such as solidified runners or flash produced during molding. See **blow molding, extruder plastic scrap; cut, kerf, and registration.** **2.** A product or material that is out of specification and not usable. **3.** See **recycled plastic; waste, industrial; waste plastic.**
scrap sorting See **recycling, automatic-sorting.**
SCR drive See **electrical SCR drive.**
screen A plate, sheet, or woven wire screen with regularly spaced openings of uniform size. Typical screens are defined by the number of wires per inch or mesh, and this screen mesh is determined by experience with trial and error, until the final product, such as an extruded product, is considered clean. All meshes are not equal. As an example, the space between the wires, which determines the size of contamination filtered, for a 100 mesh screen can vary depending on the wire diameter used. Also called *sieve.*
screen absorber See **ultraviolet absorber.**
screen pack The screen is used during the processing of melt to flow through it and trap contaminates (unmelted plastics, foreign particles, etc.). Also called *screen changer.* See **extruder screen pack; injection-molding screen pack.**
screen-pack breaker plate A perforated plate that is positioned at the rear of the die in an extruder and supports the screens. Breaker plates are used without screens in the nozzles of injection-molding machines for improving the distribution of color particles in the melt.
screw A geometric-helical flighted hard steel shaft that rotates within a plasticizing barrel to mechanically process and advance the plastic being prepared for different processes that principally involve extrusion, injection molding, and blow molding. It has a wide operating range to meet various performance requirements of the plastics processed. The goal is to obtain maximum throughput with perfect melt quality based on the limits or variabilities of the plastics, machines, and controls. The interplay among the many variables characterizes the requirements to be met by the screw. For example, the screw diameter with its geometry as well as the screw drive must be carefully selected based on melt volume and rate of travel. Many different screw designs are available to meet the desired performance for the different plastics being processed. Many thousands of plastics are processed with hundreds that make up the majority of plastics commercially being processed. See **barrel; blow molding; concentricity; extruder; heat-transfer mechanism; injection molding; melt flow; plasticator; plastic consumption; reliability; tolerance, full-indicators-movement.**
screw action The constantly turning screw augers the plastic through the heated barrel where it is heated to a proper temperature profile and blended into a homogeneous melt. The rotation causes forward transport. It is the major contributor to heating the plastic once the initial barrel heat startup occurs. The melting action proceeds through the screw as follows: (1) The feed section initiates solids conveying. Sliding with low friction on the screw and high friction on the barrel enhances this. In this section, there is also some material compacting and a little heating of the plastic. (2) At the beginning of the transition, the plastic is further heated and more compression occurs. The solid plastic is forced against the barrel causing a sliding action. This frictional heat creates a thin film of melted plastic on the inner barrel surface. (3) As the plastic proceeds down the transition, there is more melting and more compression. Usually most of the melting takes place in the transition zone. Here the plastic is divided into three parts: a compacted solid bed, a melt film along the barrel surface, and a melt pool. The melt pool is formed as the melt film is collected by the advancing flight. Most of the melting continues to be the result of sliding friction of the solids bed against the heated barrel. This is a rapid and efficient melting action similar to melting an ice cube by pushing it against a hot grinding wheel. (4) The channel depth continues to decrease as plastic progresses down the transition zone. Melting continues and the width and volume of the solids bed decreases, while the width and volume of the melt pool increases. Unfortunately, as the channel gets shallower, shear rate increases. Now the already melted plastic continues to be heated. With too high a heating, undesirable conditions can develop such as degrading the plastic. (5) Continuing downstream through the plasticator, the solids bed breaks up; the unmelted plastics are distributed throughout the channel like ice cubes in water. The efficient melting by friction of the solids bed against the barrel tends to stop. Now only less efficient melting occurs where overheating in the melt continues in the shallow metering zone. Within this zone the complete melting action should occur. (6) Plastic continues down the shallow metering section to its exit from the plasticator (screw/barrel). There is a possibility of unmelted plastics or that the melt has nonuniform temperature and viscosities. This situation of a nonuniform melt usually results in poor product performance, color mixing, and so on. Improved mixing can be obtained by reducing the screw's channel depth; however, overheating and less output occurs. Method of feeding plastics from the hopper can help (or resolve) this situation. The constant depth metering section is not considered a good mixer when improved mixing is required in this section. This is because smooth laminar flow patterns are established, causing the different portions of melt to continue to move in a fairly constant pattern so that no mixing action occurs to eliminate the problem. Screw design plays an important part in eliminating the problem.
screw action shear rate See **screw shear rate.**
screw and barrel bridging When an empty hopper is

not the cause of machine failure, plastic might have stopped flowing through the feed throat because of screw bridging. An overheated feed throat, or startup followed by a long delay, could build up sticky plastics and stop flow in the hopper throat. Plastics can also stick to the screw at the feed throat or just forward from it. When this happens, plastic just turns around with the screw, effectively sealing off the screw channel from moving plastic forward. As a result, the screw is said to be bridged and stops feeding the screw. The common solution is to use a proper rod to break up the sticky plastic or to push it down through the hopper.

screw and barrel clearance The difference in the diameters of the screw and barrel bore (diametrical clearance) or more commonly one-half the diametrical clearance, which is referred to as the *radial clearance.*

screw and barrel wear Screws and barrels are subject to adhesive, abrasive, and corrosive wear. Adhesive wear is caused by contact between the flight and the barrel. The combination is engineered to minimize such contact, but some contact is unavoidable. Plastic material can significantly influence the abrasive and/or corrosive actions. See **barrel wear; screw wear.**

screw and barrel wobble See **plasticator wobble.**

screw and plastic Since practically all plastics processed are thermoplastics, most reviews on screw design concern processing thermoplastics. When extruding thermoset plastics, the screw is usually limited in design to having a compression ratio of 1 to eliminate possible overheating of the TS. The TS cannot be permitted to overheat in the barrel or it will solidify. If it does, the screw must be removed from the barrel, and the solidified TS removed from the screw. The feature common to all plastics screw plasticators is screws with matching barrels that have at least one hopper or feeder in-take entrance for plastics and one discharge port/exiting of the melt. The essential factor in their "pumping" process is the interaction between the rotating flights of the screw and the stationary barrel wall. If the plastic is to be mixed and conveyed at all, its friction must be low at the screw surface but high at the barrel wall. If this basic criterion is not met, the material may rotate with the screw without moving at all in the axial direction and out through the die. The clearance between the screw and barrel is usually extremely small. See **melt-temperature effectiveness; screw compression ratio; screw compression-ratio determination; screw, thermoset type; troubleshooting.**

screw and plastic, general purpose The general-purpose single screws are designed to suit as wide a range of plastics as possible. They are not the ideal answer for the extrusion of specific plastics. For example, a screw designed for a semicrystalline (usually called *crystalline*) must provide initially at least a greater heat input than an amorphous thermoplastic. Thus, when a specific material is going to be used for a long run, it becomes economically very beneficial to use a dedicated screw. The design of a screw is determined by the melt flow or theoretical characteristics of the plastics; plastic material dictates screw design.

screw, auger Refers to the action of the rotating screw in advancing the plastic going from the unmelted to melted stages. See **mixer.**

screw axis A reference line of infinite length drawn through the center of the rear of the screw shank and the center of the discharge end.

screwback During injection molding, when the conventional reciprocating screw is preparing the next melt shot size, the screw moves backward.

screw barrel and feed unit See **barrel and feed unit; barrel borescoping; barrel grooved feed.**

screw, barrier Screw designs to accelerate melting for high-efficiency melting have developed along sometimes radically opposed concepts. Usually, the melting rate is controlled by providing a barrier between the solid bed and the melt pool to ensure that the solid bed does not break up prematurely and become encapsulated in the melt. An example of this concept, introduced by George Kruder of HPM, is called a *double-wave screw,* where the conventional feed and melting zones are employed until the point at which about 50% of melting is completed. At that section the melt and solids are mixed together. This is accomplished by varying the metering channel depth in a sinusoidal pattern. The mixing action alternates between very shallow, high-shear zones and rather deep, low-shear zones. The effect of this action is to promote the distributive mixing of the solid bed melt that has been thoroughly broken up with the melt pool. Thus, this action uses the residual melt pool heat to complete the melting of the remaining solids and in turn results in a very low average extrudate temperature. Other important developments have occurred that include the Uniroyal mixing screw, Hartig MC-3 screw, Davis-Standard VPB screw, New Castle Industries Efficient screw, Barr II screw, and Willert II screw. See **injection-molding nozzle-dispersion disk mixer.**

screw blister ring A raised portion of the root between flights of sufficient height and thickness to effect a shearing action of the melt as it flows between the blister ring and the inside wall of the barrel.

screw channel With the screw in the barrel, the space bounded by the interfaces of the flights, the root of the screw, and the bore of the barrel. This is the space through which the stock (melt) is conveyed and pumped.

screw-channel axial area The channel measured in a plane through and containing the screw axis. The location of the measurement is specified.

screw-channel axis width The distance across the screw channel in an axial direction measured to the periphery of the flight. The location of measurement is specified.

screw-channel bottom The surface of the screw stem or root.

screw-channel depth The distance in a radial direction from the bore of the barrel to its root.

screw-channel depth ratio The factor obtained by dividing the channel depth to the feed opening by the channel depth just prior to discharge. In constant lead screws, this value is close to but greater than the compression ratio.

screw-channel volume developed The axial area of the screw channel in one revolution about the screw axis. The location of the measurement is specified.

screw-channel volume enclosed The volume of the screw channel starting from the forward edge of the feed opening to the discharge end of the screw channel.

screw-channel width, normal The distance across the screw channel in a direction perpendicular to the flight measurement at the periphery of the flight. The location of measurement is specified.

screw check up When purchasing a screw, it is important to fully inspect the screw for at least outside diameter, channel profile, shank dimensions, and overall length. See **screw inspection.**

screw choke ring See **screw restriction or choke ring.**

screw cleaning See **aerated sand cleaning, hot; cleaning; mold cleaning.**

screw coating Various wear-resistant and protective-coating systems are used to meet the requirements of the plastic being processed, which may be corrosive, abrasive, or clinging. Types used include chrome plating, nickel plating, and those that use carbon, silicone carbide, tungsten carbide, boron, and cobalt. See **chrome plating; corrosion resistance; mold-cavity coating; nickel; nitriding; screw flight land.**

screw compression ratio (C/R) The compression that occurs on the plastic basically in the transition (or compression) section. It is the ratio of the volume at the start of the feed section divided by the volume in the metering section (determined by dividing the feed depth by the metering depth). The C/R should be high enough to compress the low-bulk unmelted plastic into a solid melt without air pockets. A low ratio will tend to entrap air pockets. High percentages of regrinds, powders, and other low-bulk materials are usually processed by a high C/R. A high C/R can over pump the metering section. See **screw, thermoset type.**

screw-compression-ratio determination A common misconception is that engineering and heat-sensitive plastics should use a low C/R. This is true only if it is decreased by deepening the metering section and not by having a shallower feed section. The problem of overheating is more related to channel depths and shear rates than to C/R. For example, a high C/R in polyolefins can cause melt blocks in the transition section, leading to rapid wear of the screw or barrel. For thermosets the C/R is usually 1 so that accidental overheating does not occur and causes the plastic to solidify in the barrel. Their barrels are usually heated using a liquid medium so that very accurate control of the melt occurs with no overriding the maximum melt heat. With overheating a TS melt solidifies. If it solidifies, the C/R of 1 also permits ease of removal by just "unscrewing" it from the screw. C/R ratio of 1 is also used for thermoplastics when the rheology so requires.

screw compression zone See **screw transition zone.**

screw, conical See **extruder, twin-screw, conical or parallel.**

screw constant lead A screw with a flight of constant helix angle. Also called *uniform pitch screw.*

screw constant taper See **screw taper.**

screw cooling Circulating cooling water or oil through the cored center section of the screw. The amount of cooling required in this pipe depends on screw design and operating parameters. Cooling is more critical for larger-diameter screws because the larger volume of melt flow requires more cooling (heat control). Superior extrusion may be achieved by optimizing cooling, but reduced output rates or surging may result unless proper processing temperatures are maintained. A definite area for cooling is at the feed entrance from the hopper. The main objective of screw cooling is to enhance the ability of the screw to advance the solid plastic feed into the extruder at the steadiest possible rate. This is accomplished by providing a more constant and lower coefficient of friction between the screw shank and the plastic. In so doing, the screw is able to rotate inside the mass of unmelted plastic solids while the forwarding of plastic melt takes place inside the barrel surface through the scraping action of the rotating screw flights. Various extrusion processors, particularly those using PVC, use screw cooling. See **coolant.**

screw core A hole or tube in the screw for circulation of a heat-transfer medium of a liquid or electric heater elements.

screw decompression zone In a vented barrel, the decompression zone exists between the first and second compression zones and allows venting of volatiles without the escape of melt. See **barrel-venting safety; screw, venting; venting.**

screw depth The perpendicular distance from the top of the thread to its root.

screw design The art of screw design is still dominated by trial and error approaches that provide the exact capabilities of the screws for a particular plastic operating under specific conditions. However, computer models (based on proper data input and, very important, the experience of the person with a set up similar to the one being studied) play a very important role. When new materials are developed or improvements in old materials are required, one must go to the laboratory to obtain rheological and thermal properties before computer modeling can be performed effectively. New screws improve one or more of the basic screw functions of melt quality, mixing efficiency, melting performance along the screw, melt heat level, output rate, output stability, and power usage or energy efficiency. See **injection-molding machine downsizing.** Thus, this technology is considered to be basically empirical or secretive; however, scientific approaches to screw designs based on an analytical melting model can be used. The production rate of an acceptable melt from a screw, which is its most important function, is often limited by its melting capacity. The melting capacity of the screw depends on the plastic properties, the processing conditions, and the particular geometry of the screw. Once the melting capacity is predicted, the screw can be designed to match the melting capacity.

screw design performance The rotating geometric-helical flighted screw mechanically plasticizes, with the help of heat and pressure at a controlled flow rate, and advances a melt to be pumped through the barrel. Plastic in the screw channel is subject to changes during operation. Each operation of the screw subjects the plastic to different thermal and shear situations. Consequently, the plasticizing process becomes rather complex. However, it is controllable and repeatable within the limits of the equipment and material capabilities. A fixed screw speed, screw pitch, and channel depth determines output. A deep-channel screw is much more sensitive to pressure changes than a shallow screw. In the lower pressure range, a deep channel will provide more output; however, the reverse is true at high pressures. Shallower channels tend to give better mixing and flow patterns.

screw diameter It is the diameter developed by the rotating flight land about the screw axis.

screw diametrical clearance See **screw and barrel clearance.**

screw, double-wave mixing See **screw, mixing, double-wave.**

screw drag flow In the screw metering section, the component of total material flow caused by the relative motion between the screw and barrel; the volumetric forward displacement of the plastic in the screw channel. Plasticator output is equal to the drag flow less the sum of the pressure flow and leakage flow. See **flow, drag.**

screw drive The entire electric or mechanical system that is used to supply mechanical energy to the input shaft.

screw drive motor A motor that rotates the plasticating screw. See **control drive, optimized; drive motor control; extruder drive; injection-molding screw drive.**

screw face The flight extending from the root of the screw to the flight land. The rear face is the side toward the feed section, and the front face is the side toward the meter end of the screw.

screw feed See **barrel feed housing.**

screw feed grooved See **barrel grooved feed.**

screw feed side opening An opening that feeds the material at an angle into the side of the screw rather than the more conventional system of feeding vertically downward on the screw.

screw feed zone The portion of the screw that picks up the plastic at the feed opening (throat) plus an additional portion downstream. Many screws, particularly for extruders, have an initial constant lead and depth section, all of which are considered the feed section. This section can be welded onto the barrel, or a separate part can be bolted onto the upstream end of the barrel. The feed section is usually jacketed for fluid heating and/or cooling. See **screw action.**

screw flight The outer surface of the helical ridge of metal on the screw.

screw flight angle See **screw flight helix angle.**

screw flight crack A hairline crack in the flight surfacing material of a screw. This is not a problem as long as pieces do not come out of the surface that usually occurs next to the edge of flight. If it happens, the screw must be repaired. See **screw rebuilding and repair.**

screw flight cutback The portion of the screw at the discharge end that is not flighted. This is normally included as part of the flight length.

screw flight depth Distance in a radial direction from the periphery of the flight and the root.

screw flight front bottom radius The fillet between the front face of the flight and the root.

screw flight front face The flight extending from the screw root to the flight land on the side of the flight toward the discharge. Also called *pushing face of flight* or *leading edge.*

screw flight full length The overall axial length of the flighted portion of the screw, excluding the nonreturn valve or smear head, in an injection-molding screw.

screw flight helix angle The angle of the screw at its periphery relative to a place perpendicular to the screw axis. The location of the measurement is specified.

screw flight land The surface of the radial extremity of the flight constituting the periphery or outside diameter of the screw. The wear surfaces, primarily the flight lands, are usually protected by welding special wear-resistant alloys over these surfaces. See **screw coating.**

screw flight lead The distance in an axial direction from the center of a flight at its outside diameter to the center of the same flight one turn away. The location of measurement is specified.

screw flight number of turns The total number of turns of a single flight in an axial direction.

screw flight pitch The distance in an axial direction from the center of the flight at its periphery to the center of the next flight. In a single flighted screw, pitch and lead will be the same, but they will differ in a multiple-flighted screw. The location of measurement is specified. Many screws have a pitch equal to the diameter of the screw (maximum diameter of the flight). This screw is called a *square pitch screw* with a helix angle of 17.7°.

screw flight rear face The face of the flight extending from the root of the screw to the flight land on the side of the flight toward the feed opening. Also called *trailing edge.*

screw front radius The radius at the intersection of the front or melt pushing side of the flight and the screw root. Usually this radius is smaller than the rear radius and may change from one portion of the screw to another.

screw heat treatment To improve performance and reduce wear on screws, different heat-annealing treatments are used based on the screw material of construction and plastics to be processed. Treatments include flame hardening, induction hardening, nitriding, and precipitation hardening. See **annealing.**

screw hub The portion immediately behind the flight that prevents the escape of the plastic.

screw hub seal A sealing device that prevents leakage of plastic back around the screw hub and is usually attached to the rear of the feed section.

screw identification Follow OEM screw specification for a given machine.

screw inspection Screws do not have the same outside continuous diameter. Specified dimensions (diameters versus locations, channel depths, concentricity and straightness, hardness, spline/attachment, etc.) need to be checked. This information should be recorded so that comparisons can be made following a later inspection. Some special equipment should be used other than the usual methods (micrometer, etc.) to ensure that the inspections can be reproduced accurately. Such equipment is readily available and actually simplifies inspections. It also takes less time particularly for roller and hardness testing. Details on conducting an inspection and conducting important processing behaviors are available from screw and equipment suppliers such as Techware Designs, subsidiary of Spirex Corp. with a computer software package called the Extruder's Technician (ET). See **barrel borescoping; barrel inspection; concentricity; inspection; screw check up; screw wear.**

screw inventory See **screw-channel volume developed.**

screw key The key, or other mechanism, where the screw provides the turning motion from the drive to be transmitted to the screw.

screw lead constant A screw with a flight of constant helix angle. Also called *uniform pitch screw.*

screw lead decreasing A screw in which the lead decreases over the full flighted length, usually of constant depth.

screw leakage flow In the metering section, leakage flow is the backward flow of plastics through the clearance between the screw flight lands and the barrel. It is usually an insignificant component of the total plastic flow.

screw length Overall axial length of the flighted portion of the screw, from the start of the feed pocket (throat) to the front end of a register or (with extruder screws or smear screws) the point where the root diameter begins to decrease. Flight length does not include any valves if they are in the system.

screw length-to-diameter ratio (L/D) The length-to-diameter ratio of a plasticating screw. With an injection-molding screw it does not include the length of the check valve, pressure cone, and tip. The diameter of the ratio is reduced to 1 so that the ratio is defined evenly, so that a 24/1 screw has a screw length 24 times it diameter. Based on the melt characteristics, there are general reasons for having short or long L/Ds. The advantages of a short screw are (1) less residence time in the barrel so that heat sensitive plastics are exposed to heat for a shorter time, thus lessening the chance of degradation; (2) the plasticator occupies less space; (3) the plasticator requires less torque, making strength of screw and amount of hp less important, particularly in an extruder, and (4) less investment cost initially and for replacement parts. Advantages for the long screws are that they (1) allow for greater output and melt recovery rates, (2) can be designed for greater mixing and more uniform output, (3) can be designed to operate at higher pressures, and (4) can be designed for greater melting with less shear and more conductive heat from the barrel. See **aspect ratio; barrel length-to-diameter ratio; degradation; residence time; screw plasticator; screw torque.**

screw marbleizing With marbleizing or mottling screws, no or very little mixing is desired. For example, a screw may have only a low compression ratio with a good portion of the screw consisting of the feed section followed by a short taper, and usually a metering section with few flights. A multiflighted screw (or a worn screw) allows colorants to stay in their own channels until exiting. These screws are used to obtain decorative effects. A typical application is a woman's cosmetic case, where a swirling or grainy effect is desired in the plastic coloration. This conventional system produces a similar pattern, but to duplicate, coextrusion or coinjection processing is used. See **coextrusion; coinjection molding; color, mottle.**

screw material Most screws and barrels are made from special steels. When low-alloy steels are used, a wear-resistant lined tube is in the bore. See **barrel composition.**

screw mechanical requirement Because screws always run inside a stronger and more rigid barrel, they are not subjected to high bending forces. The critical strength requirement is resistance to torque. This is particularly true of the smaller screws with diameters of 2.5 in. (6 cm) or less. Unfortunately, the weakest area of a screw is the portion subjected to the highest torque. This is the feed section that has the smallest root diameter. A rule of thumb is that a screw's ability to resist twisting failure is proportional to the cube of the root diameter in the feed section. Finite element analysis software has been used to obtain a more accurate determination of the stress levels. See **barrel composition; torque.**

screw-melt drag flow See **flow, drag.**

screw melt performance With screws, particularly injection types, melt is not perfect—that is, it is not perfect in temperature, consistency, or viscosity. With the passing of time, melt performance has always improved with better-quality controllable plastics and screw designs such as barrier screws and different mixing actions. More melt uniformity produces better product performance. See **melt.**

screw, melt pumping The action of a screw during plastic processing behaves like a pump. Melt under pressure is being pumped through the barrel output opening. Pressure starts building up back near the screw's feed section.

screw-melt temperature With nearly all machines, only the cylinder or barrel temperature is directly controlled. The actual heat of the melt, around the screw and as it exits, can vary considerably depending on the efficiency of the screw used and the method of operation. Factors affecting melt heat include the time that plastic remains in the plasticator (residence time); the internal surface heating area of the cylinder and the screw per volume of plastic being heated; the thermal conductivity of the cylinder, screw, and plastic; the heat differential between the cylinder and melt; and the amount of melt turbulence in the cylinder. In designing the screw, a balance must be maintained between the need to provide adequate time for heat exposure and the need to maximize output most economically. See **heat transfer mechanism melt-temperature effectiveness.**

screw metering zone A relatively shallow portion of the screw at the discharge end with a constant depth and lead that usually has the melt move 3 or 4 runs of the flight length. See **screw action.**

screw, mixing Various screw designs are used to meet a plastic's melt requirements. For example, the Spirex Pulsar mixing screw is used where low shear action is required. The Spirex Z-mixer is for the higher shear melts. See **mixer; mixing theory.**

screw, mixing and melting A screw without special mixing elements does not do a good mixing job, mainly because of the nonuniform shear acting in a conventional screw channel. Mixing is distributive or dispersive. Distributed and dispersive mixing are not physically separated. In dispersive mixing there will always be distributive mixing. However, the reverse is not always true. In distributive mixing, dispersive mixing can occur only if there is a component exhibiting a yield stress and if the stresses acting on this component exceed the yield stress. For a dispersive mixing device to be efficient, it should have the following characteristics: (1) the mixing section should have a region where the plastic is subjected to high stresses; (2) a high-stress region should be designed so that exposure to high stresses occurs only for a short time; and (3) all fluid elements should experience the same high stress level to accomplish uniform mixing. In addition, they should follow the general rules for minimum pressure drop in the mixing section, streamlined flow, and complete barrel-surface wiping action. See **compound; injection-molding nozzle dispersion disc mixer; mixer; mixing, dispersive; mixing, distributive; shear stress; static mixer; yield point.**

screw, mixing, concentric See **extruder, concentric-screw mixer.**

screw mixing device In plasticators, barrier-type mixing devices that can be used in the screws. Many dynamic mixers are used to improve screw performance. Static mixers are sometimes also inserted at the end of the plasticator. Proof of their success is shown by their extensive use worldwide. Each type of mixer offers its own advantages and limitations. These mixing elements are usually installed as near as possible to the end of the metering zone. Where practical they should not be located in a region where the melt viscosity is high. With some of these installations, such as in extruders, because they may have to operate at a lower speed to avoid problems such as surging, independently driven mixers can be used so that machines can operate at optimum speed. Other benefits of independently driven mixers involve feeding capability and performance. For example, metering pumps can inject with precision liquid additives directly into the mixer.

screw, mixing, double-wave The double-wave mixing screw has two equal width channels separated by an undercut barrier flight. The roots of each channel go up and down like a wave. The channel depth on one is shallow while the channel across the barrier is deep. This continual channel reversing forces melt back and forth across the barrier, subjecting the melt to high and low shear. Usually these mixing sections are located in the metering zone.

screw, mixing, Dulmage A screw can have a Dulmage section that is incorporated as an integral part of the screw. This design was one of the first mixing screws and was developed by Fred Dulmage of Dow Chemical Co. It has a series of semicircular grooves cut on a long helix in the same direction as the screw flights. There are usually three or more sections interrupted by short cylinder sections. This design interrupts the material flow where the melt follows the screw channel. It divides and recombines the melt many times. In this way, it works something like a static mixer. It is still used on screws that are processing certain materials such as foamed plastics.

screw mixing, Maddock The Union Carbide mixer, also referred to as the Maddock mixer, was given to the public without patent royalty charges. It consists of a series of opposed, semicircular grooves along the screw axis. Alternate grooves are open to the upstream entry. The other grooves are open to the downstream discharge. The ribs or flutes that divide the alternating entry and discharge grooves also alternate. These flutes are called *mixing flutes* and *wiping* or *cleaning flutes.* The plastic is forced over the mixing flute that has an undercut from the screw's outer diameter. The cleaning flute is narrower and has a full diameter. This mixer does an effective job of mixing and screening unmelted plastic. The plastic is pumped into the inlet groove, and as the screw rotates, the undercut mixing flute passes under it. The melted plastic ends up in the outlet or discharge groove. As it goes over the undercut mixing flute, it is subjected to high shear but for a very short time interval. The plastic is then pumped out of the discharge groove as new plastic enters over the full-diameter cleaning flute. See **screw mixing device.**

screw mixing, pin Around 1960, several companies started to place radial mixing pins in the screw root. These pins tend to interrupt the laminar melt flow and do a better job of mixing than the regular screw. Because these pins improved mixing, it is also possible to design the screw a little deeper to obtain some more output with the same degree of mixing. Many patterns and shapes (streamlined, etc.) of pins have been used. In general, they are usually placed in rows around the screw. They are located in the metering section after most of the melting has taken place. A typical arrangement would have three rows, with one row at the beginning of the metering section, another row one flight back from the end, and the third row halfway between the other two rows. Pins are usually staggered from row to row. The pins should be hardened and have an interference fit to prevent dislodgment. Pins, unlike other mixing devices, are easy to install as an afterthought. This is usually done after the screw has been running and found to need more mixing capability.

screw mixing, Pulsar In the Pulsar mixer (from Spirex Corp.), the metering section is divided into constantly changing sections. These sections are either deeper or shallower than the average metering depth. This requires all the plastic to alternate many times from shallower depth and somewhat higher shear to deeper channels with lower shear. During this changing action, it experiences a gentle tumbling and massaging action. This design interrupts the undesirable laminar flow and causes excellent mixing, distribution, and melt uniformity without high shear.

screw mixing, Saxton It has a plurality of minor flights and channels on a helix angle that is normally greater than that of the primary flight. The minor flights and channels are interrupted by major channels that are cut with an opposite hand lead. One drawback with these nonflighted interruptions is that the melt no longer has the positive forward conveyance other than pressure flow, although the interruptions on a helix are much better than tangential grooves as some barrel wiping action still takes place. The screw was patented in 1961.

screw mixing section A section added to some plasticating screws at the output end that intensively mixes the plastic.

screw, multiple See **extruder, multiple-screw; extruder, single-screw; extruder, twin-screw.**

screw, multiple-flighted A screw with more than one helical flight, such as double flighted, double lead, double thread, or two starts, and triple flighted.

screw, multiple-stage A screw that introduces special mixing sections, such as changes in the flight helix, choke rings, venting, or torpedo that combine feeding, mixing, and metering.

screw output The rate of output (throughput), or the speed at which plastics is moved through the plasticator, has continuously been pushed higher as a result of design advances in equipment and materials. Output rates generally range from a few kilograms to over 5 tons per hour on single-screw machines. Twin-screw extruder diameters have output rates ranging from a few kilograms to at least 30 tons per hour. A rough estimate for output rate (OR) in lb/h can be calculated by using the barrel's ID in inches and using the following equation: $OR = 16\ ID^2$ (lb/h $\times$ 0.4536 = kg/h). However, the output of a screw is somewhat predictable, provided that the melt is under control and reasonably repeatable. With a square-pitch screw (a conventional screw where the distance from flight to flight is equal to the diameter), a simplified formula for output is $R = 2.3\ D^2\ h \cdot N$, where R = rate or output in lb/h (kg/h), D = screw diameter in inches (mm), h = depth in the metering section in inches (mm) (for two-stage screw use the depth of the first metering section), g = gravity weight of the melt, and N = screw rpm. This formula does not take into account back flow and leakage flow over the flights. These flows are not usually a significant factor unless the plastic has a very low viscosity during processing or the screw is worn out. The formula assumes pumping against low pressure, giving no consideration to melt quality and leakage flow of several worn OD screws. See **screw volumetric efficiency; troubleshooting.**

screw output loss There are basically two methods of evaluating output loss caused by screw wear; one is rather accurate and the other is a rough approximation. The accurate method is to compare the current worn-screw output with a production benchmark reference output that was established when the screw was new. The approximate method involves determining screw wear by measuring the screw, calculating the resultant added screw to barrel clearance, and estimating the output loss from the added clearance. There are three major problems with the approximate method. First, it results in about 24 hours of machine downtime. Second, it may understate the extent of output loss by as much as 2½ times. Third, it does not account for the commonly encountered problem where the screw's rpm is simply increased, yet the output loss due to increased melt temperature is not well established.

screw performance Determination of screw performance usually starts by comparing one screw with another screw, assuming one exists for comparison. The parameters that should be considered include the following: (1) output rate, (2) extrudate melt temperature, (3) extrudate melt quality, (4) extrusion stability/pumping consistency, and (5) energy usage. Different processes will require different levels for each of the parameters listed, and these levels should be understood to allow accurate screw-design selection.

screw pitch See **screw flight pitch.**

screw, planetary A multiple screw device in which a number of satellite screws, generally six, are arranged around one longer and larger diameter screw. The portion of the central screw extending beyond the satellite screws serves as the final pumping action as in a single-screw extruder. This screw system provides special compound mixing actions, such as the discharge of volatiles toward its hopper end when processing powders such as dry-blended PVC. See **mixer.**

screw plasticator The screw in a barrel of a fabricating machine that rotates to convey and melt plastic from the hopper entrance to the front of the barrel. See **concentricity; plasticator; plasticator safety; screw length-to-diameter ratio; shear heating.**

screw plasticator frictional heat The heat that is generated within the stock as a result of mechanical working that occurs between the screw rotation and the stationary barrel.

screw plasticizing The melting and mixing action that occurs during plastication. See **injection-molding machine downsizing; plasticizing.**

screw plastic volume swept The volume of material that is displaced as the screw (or plunger) moves forward. It is the effective area of the screw multiplied by the distance of travel. See **shot.**

screw plunger transfer molding See **transfer molding, screw-plunger.**

screw pocket A place where a screw flight is initiated, usually starting from a cylindrical area or another flight. The feed pocket exists on most screws and is located at the intersection of the bearing and the beginning of the flight.

screw pressure See **melt flow; screw action.**

screw pulling See **extruder screw pulling; injection molding screw pulling; screw removal.**

screw pump ratio (PR) Applies to two-stage, vented screws and gives a measure of the ability of the second-stage to pump more than the first-stage delivers to it. A high PR will tend to surge, and a low PR will tend to cause vent melt flow. See **screw, venting.**

screw pushing flight The face or edge of the screw flight that drives the plastic forward toward the barrel exit.

screw pushing side The flight face of the screw flight that faces the discharge and runs from the front radius to the top of the flight land. This surface is usually close to being perpendicular to the axis of the screw.

screw radial clearance One-half the diameter of the screw.

screw raised register A register that has a longer diameter than the adjacent root diameter. This is sometimes supplied on injection screws having metering depths too deep to match the rear seat of a standard. See **screw tip, injection.**

screw radius The radius of the intersection of the rear or trailing side of the flight and the screw root. Usually this radius is larger than the front radius and may change from one portion of the screw to another.

screw, reactive See **extruder, reactive-processing.**

screw rear bottom radius The fillet between the rear face of the flight and the root.

screw rear seat A flat, ring-shaped portion of a nonreturn valve that abuts the front vertical face of an injection screw and seals the flow of melt by contact with the rear conical shaped end of the check ring. See **screw tip, injection.**

screw rebuilding and repair Screws and barrels are expensive and can cause downtime when damaged or worn. It may be practical (cost-efficient) to repair rather than replace. It is common practice to rebuild a worn screw with hard surfacing materials. Quite often the rebuilt screw will outlast the original screw time in service. The larger the screw, the more economical screw repairing becomes. It usually does not pay to rebuild 2 in. (50 mm) diameter or smaller screws. See **barrel wear; manufacturing, remanufacturing/rebuilding; screw coating; screw strip, polish, plating; screw wear.**

screw, reciprocating See **injection-molding machine, reciprocating-screw.**

screw recovery rate The volume or weight of a specified processable material that is discharged from the screw per unit of time, when operating at 50% of injection capacity (not applicable to extrusion). A high recovery rate can shorten cycle time and eliminate one of the reasons for a nozzle shut-off valve.

screw register The cylindrical portion of an injection screw at the most forward end that is accurately machined to match the rear seat of the nonreturn valve. See **screw tip, injection.**

screw relief An area of the screw shank of lesser diameter than the outside diameter and located between the bearing and the spine or key-way.

screw removal Before shutting down a plasticator, it is helpful to stop feeding plastic and then follow up with a purge material that will make it easier to pull the screw for changeover or maintenance. See **extruder screw pulling; injection-molding screw pulling.**

screw replacement Many processors run a poorly performing screw long after it should have been changed because replacements are expensive. Converting the cost of a screw into an equivalent volume of plastic or into a profit per day will determine payback. Assume that a screw costs $30,000 to $40,000 each with output at 3,000 lb/hr (1,400 kg/hr) of a $0.40/lb plastic. If you waste 100,000 lb (45,400 kg) of plastic, you justified the cost of the new screw. A new screw would represent 33 hr of processing. It pays to replace the screw.

screw restriction or choke ring An intermediate portion of a screw that offers a resistance to the forward melt flow of material.

screw retainer The largest nonreturn valve that threads into the injection screw. The forward portion retains the front seat or the sliding ring. The front end of the retainer is usually a torpedo or conical shape and usually is fluted.

screw reverse flight A type of extruder screw with left-hand flights on one end and right-hand flights on the other end, so that material can be fed at both ends of the barrel and extruded from the center.

screw rifled liner The liner whose bore is provided with helical grooves.

screw root or stem The continuous central shaft usually of cylindrical or conical shape.

screw rotation speed The revolutions per minute (rpm) of a screw. See **extruder screw speed; injection molding screw rotation speed; process control.**

screw rotation speed control Various control systems control speed. The arguments for the use of integral or derivative control of speed are the same as for temperature control. Speed controls permit accuracy, such as 0.5% or less. See **process control.**

screw, self-tapping See **joining, self-tapping screw.**

screw shank The rear protruding portion of the screw to which the driving force is applied.

screw shear rate Most of the energy a screw imparts to the plastic is by means of shear between the screw and barrel surfaces. The rate of energy that is imparted increases as the shear rate increases. The rate increases as the relative speed of the two surfaces increases and as the distance between the surfaces becomes less. See **energy; flow model; shear rate, melt.**

screw, single-flighted A screw having a single helical flight. See **extruder, single-screw.**

screw shot size See **injection molding machine shot size.**

screw speed See **screw rotation speed.**

screw, starve feed See **material starve feeding.**

screw static mixer See **static mixer.**

screw, stripping torque The torque at which threads are stripped out of the molded part. High stripping torque is optimal.

screw strip, polish, plating After a certain period of service, most screws become scratched, carbonized, or discolored due to the melting action. They are difficult to clean and tend to lose their original feeding characteristics. If they have been plated (usually chrome), the chrome may be gone in some places or peeling in others. It is best to refurbish a screw in this condition by stripping the old chrome, polishing, buffing, plating, and buffing again. The screw will look much better and should also perform better for little cost and a short delivery time. Most screws that are rebuilt are also stripped. See **surface finish.**

screw, strip-to-drive ratio The ratio of stripping torque to driving torque of a self-tapping screw. A high ratio provides easier assembly and a higher safety factor.

screw suck-back See **injection molding screw suck-back.**

screw taper The conical transition section or conical tapered section in which the root increases uniformly in diameter so that it is of conical shape.

screw taper constant A screw of constant lead and uniformly increasing root diameter over the full flighted length.

screw temperature zone A section of the melt-flow path that is controlled to the optimum temperature for each zone. Small machines may have only one heating zone; however, most require from two to at least six zones providing the proper temperature profile of the melt within the plasticator. See **process control; screw action; temperature.**

screw, thermoset type The usual TS plastic, being very heat sensitive, uses a compression ratio of 1 with a water-cooled barrel to provide positive temperature control. During plasticizing, if the temperature goes just slightly too high, the melt solidifies in the barrel requiring screw pulling and its removal. See **screw and plastic; screw compression ratio; thermoset plastic.**

screw thread, molding See **molded screw thread.**

screw thrust The total axial force exerted by the screw on the thrust bearing (screw support). For practical purposes, it is equal to the melt pressure times the cross-section of the barrel bore.

screw thrust bearing The bearing used to absorb and support the thrust force exerted by the screw. See **bearing.**

screw tip The forward end section of a screw. A variety of sizes and shapes are available to meet the requirements of the plastic being processed, such as their viscosity. See **viscosity.**

screw tip, back-flow stop valve See **screw tip, injection.**

screw tip, castle valve A value that has a series of fingers that interlock with slots on its retainer ring. This requires the ring to turn with the screw, which eliminates wear between the ring and front seat. Side loading is applied to the interlocking components, making this interface critical.

screw tip, injection When the melt is forced into the mold, the screw's plunger action could cause the melt to flow back into the screw flights. Generally, with heat-sensitive plastics such as PVC and thermoset plastics, a plain or smeared head screw tip is used; it has a tapered shape that conforms to the barrel taper just prior to the nozzle opening, eliminating back flow. For other plastics this is not adequate, and a number of different check valves are used, each with certain advantages and disadvantages. These devices work in the same manner as a check valve in a hydraulic system, allowing melt to pass only in one direction. They have a sliding ring, restricted floating ball, and their combinations. See **injection molding machine ball-check valve; injection molding machine ring check valve.**

screw, thread-cutting See **joining, thread-cutting screw.**

screw torpedo **1.** An unflighted cylindrical portion of the screw that is usually located at the discharge end and provides additional shear heating capabilities for certain plastics. **2.** In an injection-molding plunger machine (no screw used), a solid streamlined block of metal that fits near the exit end of a barrel, restricting the plastic flow. It causes the melt to develop heat during shearing action. Some of these are rotating to provide additional melting action. Also called *spreader.* See **spreader.**

screw torque The work of melting is done by rotating the screw in a stationary barrel. The rotational force called *torque* is the product of the tangential force and the distance from the center of the rotating member. For example, if a 1 lb (0.454 kg or N) weight was placed at the end of a 1 ft (0.035 m) bar attached to the center of the screw, the torque would be 1 ft × 1 lb or 1 ft-lb (1.36 Nm). Torque is related to horsepower (hp), which equals [torque (ft-lb) × rpm]/5,252 or kW = [torque (Nm) × rpm]/7,124. The torque output of an electric motor of a given hp depends on its speed. A 30 hp (22 kW) motor has the following torque at various speeds: 87.5 ft-lb (119 Nm) at 1,800 rpm, 133 (181) at 1,200, and 175 (238) at 900. See **extruder specification feed system; joule; screw length-to-diameter ratio.**

screw torque speed The speed of a given hp motor is built into the motor. Changes in speed and torque can also be accomplished by changing the output speed of the motor by using a gear train. The change in torque varies inversely with the speed. For example, if an alternating-current motor is used, it will develop a starting torque of almost twice the running torque. The screw has to be protected against overload to prevent screw breakage. This is not a problem with hydraulic drives. The drive must supply enough torque to plasticize at the lowest possible screw speed but not enough to mechanically shear the metal screw. Different torque requirements are used to meet the requirements of the different plastics. For example, much higher torque is required to plasticize polycarbonate than polystyrene. The strength that is used limits the input hp. Using little torque to turn the screw indicates that the heater bands are providing too much of the energy required to melt the plastic, usually as a result of poor or no temperature control. Plastication efficiency suffers in these conditions, and mixing problems or long, inconsistent recovery times are symptomatic of this condition.

screw trailing edge The flight face of the screw that faces the feed end and runs from the rear radius to the top of the flight land.

screw trailing flight The rearward part of the screw flight.

screw transfer molding See **compression molding, screw preplasticator; transfer molding.**

screw transition zone The section of a screw between the feed zone and metering zone in which the flight depth decreases in the direction of discharge. In this zone the plastic starts in both solid and molten states with the target being to have all molten on leaving this zone. Also called the *compression zone.* See **screw action.**

screw transition zone, conical and involute The two basic types of screws are conical and involute (or spiral), with each providing different situations based on the theories used. The conical transition has a root that is cone shaped and is not parallel to the axis of the screw. The involute transition has a root that is always parallel to the screw axis, and the channel depth varies uniformly. Actually, the use of the word *involute* is not correct in geometric terms, but most people working with screws know about this situation. With the involute, one side is deeper than the opposite side, causing an unbalanced screw so that at high pressures it causes rapid wear. Surges also can occur since solid plastic blocks are formed. The disadvantage of the conical is that it is more difficult to machine and more expensive.

screw transition zone, wrap-around A transition section in which the root is always parallel to the axis of the screw.

screw, twin See **extruder, twin-screw; extruder, twin-screw, conical or parallel.**

screw, two-stage See **screw, venting.**

screw valve See **screw tip.**

screw, venting In a plasticator (extruder, injection-molding machine, blow-molding machine, etc.) melt must be freed of gaseous components such as moisture and air from the atmosphere and from plastics, plasticizers, and other additives as well as entrapped air and other gases released by certain plastics. Gas components such as moisture retention in and on plastics have always been a problem for all processors. All kinds of problems develop on products (splay, poor mechanical properties, dimensions, etc.). This situation is of particular importance when processing hygroscopic plastics. One major approach to this plastic degrading situation is to use plasticators that have vents in their barrels to release these contaminants. It is very difficult to remove all the gases prior to fabrication, particularly from contaminated powdered plastics, unless the melt is exposed to vacuum venting (in most vented screws, a vacuum is connected to the vent's exhaust port in the barrel).

The standard machines operate on the principle of melt degassing. The degassing is assisted by a rise in the vapor pressure of volatile constituents, which results from the high melt heat. Only the free surface layer is degassed; the rest of the plastic can release its volatile content only through diffusion. Diffusion in the nonvented screw is always time-dependent, and long residence times are not possible for melt moving through a plasticator. Thus, a vented barrel with a two- or three-stage melting screw is used. Those with one vent use a two-stage screw that basically looks like two single screws attached in series. Where the two meet, there is a very shallow channel section so that when the melt reaches that section, no melt pressure exists. In turn gaseous materials are released through a port opening. With those having two vents, a three-stage screw is used that provides another stage to eliminate contaminants. See **air vent; barrel-venting safety; bleed; extruder venting; injection molding, venting; screw decompression zone, venting; screw pump ratio; venting; venting purifier.**

screw, venting, basic The first stages of the transition and metering zones are often shorter than the sections of a single-stage conventional screw. The melt discharges at zero pressure into the second stage, under vacuum instead of pressure. The first-stage extrudate must not be hot enough to become overheated in the second stage. And the first stage must not deliver more output per screw rotation at discharge pressure than the second-stage can pump through the barrel under the maximum normal operating pressure. This usually means that the second-stage metering section must be at least 50% deeper than the first stage.

screw venting bleeding The unplanned escape of melt bleeding through the vent during operation of the vented barrel processing. See **vent bleed.**

screw, venting ratio In practice the best metering-section depth ratio (pump ratio) is about 1.8:1. The ratio to be used depends on factors such as screw design, downstream equipment, feed stock performance, and operating conditions. There is likely to be melt flow through the vent (avoid this situation) if the compression ratio is high or the metering depth ratio is slightly too low. If the metering depth ratio is moderately high, there is a gradual degradation of the output. With the screw channel in the vent area not filling properly, the self-cleaning action is diminished, and the risk of plate-out increases. In any case, sticking or smearing of the melt must be avoided, or degradation will accelerate.

screw volumetric efficiency The volume of plastic that is discharged from the machine during one revolution of the screw, expressed as a percentage of the developed volume of the last turn of the screw channel. See **screw output.**
screw wear The wear in screw plasticators generally causes an increase in the clearance between screw flight and barrel. It often occurs toward the end of the compression section. This type of wear is more likely to occur when the screw has a high compression ratio. Regardless of where this erosion of metal occurs, the plasticator's melting capacity is reduced. If the wear is serious enough, it will affect the process so that products exit at a slower rate or more likely produce a lower-quality product at the end of the line. The mechanism that causes wear includes adhesive wear (metal to metal contact under high stress), abrasive wear (galling), laminar wear (thin outer layers of metal interface wear), surface-fatigue wear (micro- or macroscopic separation from the surfaces), and corrosion wear (chemical reaction and mechanical attack of the sliding surfaces). See **injection molding reinforced plastic; screw and barrel wear; screw compression ratio; wear.** To circumvent this situation the screw should be inspected and measured on arrival (or thereafter) and regularly be inspected and have its dimensions checked. Clean-up of the screw is a good time to measure and inspect. By extrapolating to the maximum allowable wear, one can determine when the screw or barrel should be replaced or rebuilt. See **concentricity; inspection; screw inspection.**
screw-wear loss Output loss due to screw wear can be determined by comparing the worn screw's current output with the initial production benchmark, which was originally determined by shooting into a "bucket" to check the weight for a definite time period. Another approach is to measure the worn screw's clearance to the barrel wall (W), which is used along with the original measured screw clearance (O), and the metering depth (M) from the screw root to the barrel wall. Here the approximate percentage output loss (OL), with rpm being constant, is calculated from the formula $OL = (W - O)/M + 100$.
screw-wear protection Most screws are made of medium-carbon-alloy steel usually hardened to 28 to 32 RC. It is then nitrided (gas or ion) or chrome-plated for better wear resistance. Screws with improved abrasion resistance can be made of vanadium-bearing tool steel hardened to 54 to 56 RC. Cost and brittleness generally limit such screws to less than 90 mm in diameter. Materials with improved corrosion resistance are used such as precipitation-hardened stainless steel and nickel alloys. The outer diameter of the flights is the area of the screw most susceptible to wear. The most common means of protecting that area is to weld on a hard-facing alloy.
scrim See **fabric scrim.**
SCRIMP See **reinforced-plastic SCRIMP process.**
scrubber A device that is used to filter out unwanted pollutants, such as acid gas emissions at combustion facilities. It is usually a process involving water. See **gas burn; incineration fume system; pollution, air.**
scrubbing The process for removing one or more components from a mixture of gases and vapors by passing it upward and usually countercurrent to and in intimate contact with a stream of descending liquid, the latter being chosen so as to dissolve the desired components and not the others.
scuffing See **defect; marking.**
seal **1.** A method of bonding mating surfaces under controlled applications of heat, pressure, and dwell time. See **packaging. 2.** A hermetical seal or weld that is impervious to liquids, air (airtight), or other gases that cannot enter or escape. See **packaging, modified-atmosphere. 3.** A continuous joining process of two or more surfaces of sheet materials, such as those made by adhesion and fusion. See **adhesive; fusion; laminate. 4.** A seal is required in certain products, such as building insulation panels and packaging, that require a barrier against liquids, gases, or solids. See **barrier.**
sealant A material in paste or liquid form that is applied to all types of joints that cure in-place, forming a seal against gases, liquids, or outdoor weather. See **adhesive gap filling; caulking compound.**
sealant design See **design, sealant joint-shape.**
sealing See **adhesive; bonding; welding.**
sealing, dielectrically See **heating, dielectric.**
sealing, gap-filling See **adhesive gap filling.**
sealing, heat A method of joining plastic films by the simultaneous application of heat and pressure to the areas in contact. Heat can be applied using hot plate, dielectric heating and radio frequency welding. Also called *thermal heat sealing* or *heat sealing*. See **sealing, impulse; sealing, ultrasonic; welding.**
sealing hinge with closure See **closure; design hinge, integral.**
sealing, hot knife A joining process in which a heated tool in the form of a knife blade is passed between the parts being joined, so that heat is applied to the seal side of the part. The blade is then removed, and surfaces are pressed together for a few seconds until the bond solidifies.
sealing, impulse A radio-frequency pulse applies an intense thermal energy to the sealing area for a very short time period where heat develops, followed immediately with cooling the seal. The heated metal bar could include an internal channel for cooling.
sealing, medical See **medical seal and closure.**
sealing, O-ring A product of precise dimensions that is molded in one piece to the configuration of a torus with circular cross-section and is suitable for use in a mechanical groove for static or dynamic service.
sealing temperature The temperature of a thermoplastic film or sheet that is required to join two or more films or sheets in contact by fusion. See **sealing, heat.**
sealing, ultrasonic A vibratory mechanical pressure at ultrasonic frequencies (20 to 40 kc) is applied to the mating thermoplastic parts to produce a bond or seal. Electrical

energy is converted to ultrasonic vibrations through the use of either a magnetostrictive or piezoelectric transducer. The vibratory action and pressure applied at the interface develops localized heat that melts the contacting surfaces followed by a cooling action. See **adhesive; bonding; insertion, ultrasonic; sealing, heat; welding.**

search, blind A systematic search that does not involve intelligent decision making.

search, brute force method A means of problem solving that consists of simply trying all possible solutions without regard to using heuristics to eliminate blind paths or approaches.

seat See **automotive seat.**

sea water desalination See **water, ocean desalination of.**

secondary bonding forces, molecular See **temperature and molecular bonding force.**

secondary equipment See **auxiliary equipment; fabricating processing type.**

segregation **1.** In thermoset plastics, a separation of plastic and filler on the surface. **2.** With thermoplastics, a close succession of parallel, relatively narrow, and sharply defined wavy lines and color striations on the surface that differ in shade from surrounding areas and create the impression that the components have separated.

Selar DuPont's trade name for its barrier plastic that is a modified nylon with a compatibilizer or binder applicable to other plastics, such as in gasoline PE fuel tanks.

selecting process See **design, optimized; fabricating process type.**

selection, material See **plastic material selection; statistical material selection, reliability of.**

self-cleaning See **reaction-injection molding self-cleaning.**

self-extinguishing See **flame extinguished.**

self-heating See **heating, self-.**

self-ignition See **combustion, autoignition point.**

selvedge See **fabric selvedge.**

semiconductor **1.** A material with controllable conductivities between insulators and conductors. See **dopant; electrical conductivity; element, semiconductor; plastic, light-switchable. 2.** In pure metals, where electrons are excited across the energy gap.

semicrystalline plastic A material that exhibits a high degree of crystallinity with a small degree of amorphous structure. However, these plastics are usually called *crystalline plastics.* See **amorphous plastic; crystalline plastic.**

semifinished product See **product, semifinished.**

semipermeable See **membrane.**

sensitivity The minimum input capable of producing an output motion. Also called *gain.*

sensor A device that is designed to respond to a physical stimulus (color, gloss, temperature, pressure, motion, illumination, time, velocity, weight, etc.) and transmit a resulting signal for interpretation, measurement, or operating a control. Sensors vary in their sensitivity, capability, and repeatability. They include air, beta ray, electrical caliper, capacitance, infrared, laser, magnetic reluctance, mechanical motion or contact, nuclear, optical, proximity, scales, sonic, strain gauges, thermal element, ultrasonic, and x-ray. To select the correct sensor one should know something about how they work and limitations existing such as thickness and type of plastic. There are those that transmit or reflect as well as those that have contact or noncontact. Also called *transducer.* See **control actuator; measurement; plastic, smart; radioisotope; tensile gauge length; transducer.**

sensor accuracy Available accuracy depends on factors such as the static accuracy ratings, source errors, long-term repeatability, and noise factors. Some sensors work only in certain environments. For sensors' or transducers' information to be accurate, they must be properly calibrated. See **accuracy; design accuracy.**

sensor, beta gauge A gauge that consists of two facing elements—a β-ray-emitting source and a β-ray detector. For example, when a film or sheet is passed between the elements, some of the β-rays are absorbed, and from the percentage absorbed the area density and/or thickness can be determined. Also called a *beta-ray gauge.* See **beta.**

sensor, caliper A gauge that provides for direct physical measurement of the total thickness. Depending on type, the sensors may contact on both sides or have one or both sides riding on a thin, controlled air film.

sensor, capacitive A location or thickness sensor that uses the presence of the plastic as a dielectric in a circuit to provide continuous readouts.

sensor, chemical indicator See **sterilization chemical indicator.**

sensor, dual laser A double laser beam is used to measure, for example, pipe diameters on two axes during the extrusion of pipe. See **extruder, pipe and tubing.**

sensor, dynamic accuracy of a The indication of how a sensor will operate in the production environment. It is defined as a comparison of sensor readings on, for example, a sheet with actual samples taken from the sheet and measured. It is a function of a number of variables of which sensor static is one. Others include flutter sensitivity, air gap temperature, mechanical sensor alignment, and sensor's response time. Real-time inspections can be made at speeds up to at least 4,300 ft^2/min (400 m^2/min). Imperfections down to 125 microns on coated extruded film webs can be found at speeds of at least 820 ft/min for 5 ft widths (250 m/min for 1½ m). See **inspection; sensor, laser.**

sensor, electron optical A device that produces and controls a beam of electrons to produce an image.

sensor, fiber-optic Strain gauges use fiber optics to sense and record mechanical loadings on products. See **fiber optic; strain gauge; stress-strain curve.**

sensor, film and sheet Sensors for measuring thickness usually fall into one of three categories: nuclear, infrared, and caliper.

sensor, gamma backscatter A nuclear gauge that is based on the use of a gamma-ray-emitting source and a gamma-ray detector. It can handle thicker sections than beta gauge techniques.

sensor, inductive and capacitive proximity A sensor that detects the presence or absence of metallic and nonmetallic products without physical contact. See **bottle sorter, optical; contamination; recycling, automatic-sorting; sensor, nuclear.**

sensor, infrared (IR) A sensor that measures mass per unit area and then converts the measurement to a thickness value. Unlike nuclear types, which measures the total weight of a product, an IR can sometimes be tuned to measure different materials independently. However, their versatility is not a sign of their universal application. They are best applied to clear films and coatings as well as melts during processing (extrusion, injection, etc.) and are not particularly well suited to opaque films or films containing certain additives and fillers. The effect of many of the additives and fillers can be minimized through a careful selection of the wavelengths measured. During polyethylene blown-film manufacture, an IR temperature sensor can indicate the bubble's crystallization or freeze line height. These lines correlate with key fabrication variables such as blow-up ratio and the film's properties. There are basically the two configurations of transmission and reflection. Each is suited to different applications. See **electromagnetic spectrum; extruder-blown film blow-up ratio; infrared; inspection, infrared.**

sensor, intelligent Intelligent programmable sensors enable flexible manufacturing as they are quickly and easily reconfigured for small batch runs of a specialty or custom product. Many take over the difficult inspection and positioning tasks that a few years ago required an expensive, full-scale computer-controlled vision-inspection system. The sensors are programmable, easy to set up and reconfigure, and provide affordable and accurate inspection and positioning applications. The need for human operators is often eliminated. See **robot, intelligent; transducer, magnetostrictive.**

sensor, laser A sensor that is only effective with opaque materials and particularly thick materials. If a processor has a sheet product that varies in density and needs to know the true thickness, a laser can measure part dimensions and control dimensions, such as of an extruded pipe. See **extruder pipe and tubing; laser; strain extensometer, laser beam.**

sensor, noise effect Elimination of noise, in regard to sensors, is accomplished through an averaging technique. This can be done because noise typically takes on a random nature and as a result can be filtered or eliminated over time. The error effect of short time variation, which is one type of noise, consists of the deviation from the average value during a specified sample time period. Noise can come from a number of sources, but as long as it is random, it can be reduced to acceptable limits over sufficient time. See **noise.**

sensor, nuclear A beam of beta or gamma radiation is passed through a material that is being measured for thickness. The greater the mass of material, the less radiation is able to pass through the detector. If the material is of constant density, sensor calibration can be in units of thickness. They can measure only total thickness, not individual pieces, if laminated. Beta provides somewhat faster response; gamma can handle much thicker material. See **bottle sorter, optical; radiation; recycling, automatic-sorting; sensor, inductive and capacitive proximity.**

sensor, piezoelectric A sensor that provides readouts that can be extremely fine tuned at high speed using the piezoelectric effect. See **piezoelectric effect.**

sensor, ultrasonic A sensor that is used in different fabricating processes to control dimensions, such as an extruded blown-film bubble diameter, or to measure extruded pipe diameter and concentricity. See **ultrasonics.**

sensor vision See **computer image-processor; inspection; vision system.**

separator **1.** A layer of material that acts as a release film during certain processes. **2.** A permeable material, such as a fluoroplastic-coated glass-fiber fabric. For example, it is used between a reinforced plastic lay-up and a bleeder system to remove unwanted plastic or gases developed during a thermoset plastic curing cycle such as during bag molding. See **reinforced plastic bag molding; reinforced plastic separator. 3.** In the waste and recycling business, separating the different substances that are collected. See **recycling; waste.**

separator, balisic The balisic machine sorts inorganic from organic matter for composting purposes.

sequencing See **production prioritizing.**

sequestering agent A material that prevents metallic ions from precipitating from solution by means of reactions that normally would cause precipitation in the absence of this agent. See **solution.**

serendipity An unexpected engineering or scientific discovery that turns out to be more important than the project being researched or developed.

serum See **latex serum.**

serviceability The ability of any equipment or instrumentation to be easily serviced or maintained and thereby avoid costly downtime. An important consideration when making purchases. See **maintenance; technical service; troubleshooting.**

service condition The exposure to factors such as heat, cold, flexing, impact shock, or creep loads to which a material or product will be subjected. The conditions are usually specified for different operations, such as fabricating or testing.

service distribution See **plant control.**

servo control A control in which the principle objective is to follow a reference value that varies with time. With closed-loop servos and digital interfaces, faster flow of more information is achieved between the motion controller and the motors. This information allows for more precise adjustments, faster speeds, higher repeatability, and better performance. The results are higher outputs (reduced cycle time, etc.), improved quality, and more predictable processes. See **computer monitoring infor-**

mation; drive-system control; computer analog-to-digital converter, control, closed loop; control drive, optimized; fabricating output; motion-control system.

servo-control-drive reliability Some servo drives have a mean time between failures that is measured in decades. Proven reliability means years of machine uptime. Servo systems with brushless AC servo motors and solid-state drive performances can provide extremely high reliability rates, even in the most demanding environments. All-digital servo systems can pinpoint a fault for the fastest possible mean time to repair. By replacing mechanical line shafts and other gear-train assemblies, servos provide for simpler mechanical systems, reducing the mechanical complexity of a machine design. See **electric motor drive; mean.**

servo system See **motion-control system; motion-control system type.**

set To cause a specific condition, such as solidifying a plastic melt. Sets can be designated by different conditions. **1.** Basically the conversion of a liquid plastic into a solid or semisolid state. See **adhesive set; strain set. 2.** The strain remaining after complete release of the force producing a deformation. See **tension set. 3.** The conversion of a plastic into a fixed or hardened state by chemical or physical action, such as condensation, polymerization, vulcanization, or gelatin.

set at break See **elongation, set at break; test set, immediate.**

set immediate See **test set, immediate.**

set point See **fabricating process set point.**

setting See **fabricating process setting.**

setting up Additional hardening time. See **molded-part setting-up.**

sewer rehabilitation Since at least the 1950s, cured-in-place reinforced plastics, such as thermoset polyester plastic with hybrid reinforcement fiber felt tube patterns have been used to repair deteriorated or corroding municipal sewer lines that are made of concrete or steel and that may be only 30 years old. The process may require very little (if any) excavation, and sewer lines can be repaired quickly, with minimal disruption of traffic and services and at a significantly lower cost when compared to other processes. The process uses a prepreg cured-in-place reinforced plastic tube to reconstruct the underground pipe inner wall. It starts with a flexible felt tube (round or any shape) that is plastic coated on the inside and impregnated through the outside principally with Amoco Chemical's purified isophthalic (OIA) thermoset polyester plastic (very corrosion resistant, high strength, and easy to process). The uncured wet pliable prepreg tube is inserted through an existing manhole or other access point. After installation, water pressure is used to force the prepreg against the old pipe, and the water is heated to cure the plastic. See **pipe, deteriorating; prepreg; reinforced plastic pipe; reinforced plastic preimpregnated; safety; sleeving; underground pipe.**

S-glass See **fiberglass type.**

shape See **die shape; product shape.**

shape and volume change See **dilatant.**

shape, blow mold complex See **blow molding, extruder, three-dimensional.**

shape, concave A surface that curves inward, such as the inner surface of a food bowl. See **surface.**

shape, convexity That portion or place on an object that protrudes as a roughly spherical shape.

shape, convex A surface that curves outward, such as the surface of a sphere.

shape measurement See **deflection; machine, coordinated measuring.**

shape, molecular See **Staudinger, Hermann.**

shaping mechanically Controlled mechanical operations for shaping a product at temperatures above the recrystallization temperature. See **mold.**

shark-skin surface See **extruder shark-skin surface.**

Shaw pot See **transfer-molding Shaw pot.**

shear An action of stress that results from applied forces and that causes or tends to cause two contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact. It is the stress developed because of the action of layers in a material attempting to glide against or separate in a parallel direction. See **orientation, accidental.**

shear edge See **mold shear edge.**

shear energy See **screw shear rate.**

shear failure The movement that is caused by shearing stresses and that is sufficient to destroy or seriously endanger a structure. Also called *failure by rupture.* See **rupture.**

shear force A force that is directly parallel to the surface element across which it acts.

shear fracture A mode of fracture in crystalline materials that results from translation along slip planes that are preferentially oriented in the direction of the shearing stress.

shear heating The heat that is produced within the plastic melt as the plastic layers slide along each other or along the metal surfaces in a plasticating chamber of the processing machine. See **screw action.**

shearing The breaking that is caused by the action of equal and opposed forces that are located in the same plane.

shear, interlaminar A shearing force that tends to produce a relative displacement between two laminae along the plane of their interface.

shear joint A joint design that is used in welding in which the thermoplastic parts melt in a telescoping action due to a small interference in one of the mating parts. See **welding, ultrasonic, shear joint.**

shear melt rate See **injection-molding melt-shear behavior; melt shear rate; orientation, accidental.**

shear modulus The ratio of shearing stress to shearing strain within the proportional limit of the material. See **modulus of elasticity; proportional limit; stress-strain curve; torsional modulus of elasticity.**

shear modulus, complex The vectorial sum of the shear modulus and the loss modulus. It is analogous to a complex dielectric constant. See **dielectric constant, complex.**

shear plane A plane along which failure of material occurs by shearing.

shear proportional limit See **proportional limit; stress-strain curve.**

shear rate The time rate of change of shear strain. For a one-dimensional flow, it is the velocity gradient. See **design, basics-of-flow die; flow model; screw shear rate; viscosity; viscosity, non-Newtonian flow.**

shear rate, melt The overall velocity over the cross-section of a channel with which molten plastic layers are gliding along each other or along the wall in laminar flow. See **injection-molding melt-shear behavior; mathematical equation, cross-.**

shear rate, melt sensitivity Most plastic melts are pseudoplastic; at increasing shear rates they become less viscous. However, the relative degree of shear sensitivity varies greatly from one plastic to another. Generally, broadening MWD produces increasing shear sensitivity.

shear roller See **compounding, shear-roll.**

shear, short beam See **flexural test, short-beam shear.**

shear spinning, melt See **viscosity.**

shear strain The tangent of the angular change that is caused by a force between two lines originally perpendicular to each other through a point in a body. With this strain, there is a change in shape. Also called *angular strain.* See **reinforced-plastic test, extensional-shear coupling; strain.**

shear strength **1.** The ability of a material to withstand shear stress. It is calculated from the maximum load during a shear or torsional test and is based on the original cross-sectional area of the test specimen. See **sandwich facing material; shear; strength; stress; torsional strength.** **2.** The stress at which a plastic fails in shear.

shear strength, short-beam The interlaminar shear strength, for example, of a parallel fiber reinforced-plastic material as determined by a three-point flexural loading of a short segment cut from a ring-type specimen. See **test, NOL ring.**

shear stress **1.** The component of stress that is tangent to the plane on which the forces act. Shear stress is equal to the force divided by the area sheared, yielding psi (MPa). **2.** The stress that is developed in a plastic melt when the layers in a cross-section are gliding along each other or along the wall of the channel in laminar flow. See **CAMPUS database; processing fundamental; rheometer, dynamic; viscosity.**

shear stress-strain The shear mode involves the application of load to a material specimen in such a way that cubic-volume elements of the material comprising the specimen become distorted, with their volume remaining constant but the opposite faces sliding sideways with respect to each other. Shear deformation occurs in structural elements subjected to torsional loads and in short beams subjected to transverse loads. Shear stress-strain data can be generated by twisting a material specimen at a specified rate while measuring the angle of twist between the ends of the specimen and the torque exerted by the specimen on the testing machine. Maximum shear stress at the surface of the specimen can be computed from the measured torque and the maximum shear strain from the measured angle of twist. See **stress-strain curve.**

shear stress-torque See **torque-shear stress.**

shear stress yield point See **yield point.**

shear test See **test, short-time-behavior.**

shear thinning See **melt flow analysis.**

shear torsional test See **test, torsional.**

shear yield point See **yield point.**

sheathing Cellulosic fiberboard that is used in housing and other building construction and that may be integrally treated, impregnated, or coated (plastics, etc.). It provides additional water resistance. See **coating; impregnation.**

sheathing compound See **compound, sheathing.**

sheave Pulleys and belts that are made with various materials, including plastics, which provide wear and tear resistance and heat and weather resistance. They are used to connect motors and gear reducers in different processing equipment.

sheet Any material that is fabricated into sheet form and cut to suit in further processing or use. See **antiblocking agent; calender; die, film and sheet thickness; extruder-blown film; extruder flat film; fiber fibrillation; fiber processing; film, cast; paint.**

sheet and film market See **film and sheet market.**

sheet and film thickness See **die, film and sheet thickness.**

sheet blocking The tendency of sheets or films to stick together under light pressure, such as when stacked. See **antiblocking agent; blockage; film blocking.**

sheet casting See **film, cast.**

sheeter line Parallel scratches or projecting ridges that are distributed over a considerable area of a plastic sheet (or film).

sheet-fed gravure printing See **printing, gravure.**

sheet forming See **forming, stretch and draw ratios for pressure.**

sheeting Plastic whose thickness is extremely small in proportion to its length and width and that has plastic present in a continuous phase throughout, with or without filler.

sheet, laminated Plastic sheets that are stacked together to form a construction that meets desired requirements, such as a thicker material, combining different materials, providing some type of barrier, or providing a decorative multiple layup.

sheet manufacture See **extruder sheet.**

sheet-molding compound (SMC) Originally SMC was called *prepreg*, which refers to thin or single-ply woven reinforced-fiber sheets, usually impregnated with a plastic. The term *prepreg* caused confusion, so the Reinforced Plastics Division Board Members of the SPI (now called the Composite Institute) designated the material sheet-molding compound. SMC is usually glass-fiber-reinforced thermoset polyester plastic compound in sheet form. Reinforcement can be of different configurations according to performance requirements. Chopped or long fibers are used in different woven or nonwoven fabric patterns. The sheet can be rolled into coils during their continuous processing operation. A film covering separates the layers to prevent contamination, sticking of plies, and monomer evaporation. SMC is formulated (prepared) in-house or by compounders. See **bulk molding compound; directional property; fabric; fiber; mixer-blender with impeller; mold, compression shear-edge; molding, sheet molding compound and vacuum press; polyester plastic, thermoset; prepreg; reinforced plastic sheet molding compound.**

sheet molding compound and bulk molding compound recycling SMC and BMC scrap is mechanically reduced to finely ground powder and used as a filler in different plastics. For example, 20wt% of the calcium carbonate in SMC or BMC formulations can be this powder. The recycled scrap can be produced by the following procedure: (1) preliminary size reduction, (2) metal separation and further reduction (hammer mill, etc.), (3) fractionation with integrated drying, and (4) sieving. The scrap can also be incinerated safely and provide a heating value at least equal to domestic refuge (roughly 10,000 kJ/kg). See **bulk molding compound; calcium carbonate; granulator; mill, hammer; reinforced plastic material, sheet molding compound; screen.**

sheet molding compound, structural These SMCs include the use of continuous and short glass fibers. The higher performance type, called SMC-S, contain up to at least 65wt% of glass fiber.

sheet, optical See **troubleshooting optical sheet.**

sheet orientation See **directional property; orientation.**

sheet overlay Either a nonimpregnated or plastic impregnated fabric, paper, sheet, film, or other material (aluminum foil, etc.). It is placed on the surface of a material to be processed or bonded during processing or after a part has been fabricated to provide certain advantages for decorative and industrial sheet, film, laminate, or reinforced plastic. The overlay provides wear resistance, moisture resistance, or a barrier to certain elements. Impregnated material is usually translucent when produced but becomes transparent when pressed on substrate to become a homogeneous part of the structure. The decorative sheet may have its decoration on the under side so that it is protected, or it may have another, very thin, protective overlay to reduce or eliminate abrasion problems when in use. Also called *surfacing mat* or *top sheet.* See **aluminum foil; decorating; impregnation; laminate; reinforced-plastic surfacing mat; reinforced-plastic surfacing veil.**

sheet skiving See **film, skived.**

sheet sliced See **trim.**

sheet slippage and tearing See **extruder-web tension control, slipping and tearing.**

sheet thickness See **die, film and sheet thickness.**

shelf life The time during which any material retains its storage stability under specific temperature environmental conditions so that it remains suitable for fabrication. This term should not be confused with *pot life.* Also called *storage life* or *working life.* See **cure; inhibitor; material handling; pot life; storage.**

shellac One of the first natural plastics that was used for its plastic behavior and originally mentioned in very ancient Indian texts. It is secreted by the insect *Laccifer lacca (Coccus lacca)* and deposited on twigs of trees in India. After collection, washing, purification by melting and filtering, and forming into thin sheets, it is fragmented into flakes for use as varnishes and coatings. See **lac; varnish.**

shell flour Fillers obtained by grinding the shells of walnuts, peanuts, and coconuts. Generally such fillers impart a smooth surface and medium gloss to moldings. They have lower water absorption and higher dielectric strength than cotton and wood additive fillers. See **additive; dielectric strength; flour.**

shell molding See **foundry shell molding.**

shielding See **ablative plastic; electromagnetic interference.**

shim Various materials (reinforced plastic, thermoplastic sheet, etc.) are extensively used in correcting mismatching or repairs of equipment.

shine A desirable or undesirable surface texture. When not desired, the processing easily can cause it. For example, a dirty or worn mold or lack of sufficient pressure during molding can be a problem. See **molding.**

shipment, material See **contamination; material contamination; rail car contamination.**

shipper fee See **cost, demurrage.**

shock pulse A substantial disturbance characterized by a rise of acceleration from a constant value and decay of acceleration to the constant value of time. See **elastomer.**

shoe See **cement construction; filament shoe; nail.**

shoe, upper See **poromeric.**

shop-right See **legal matter: shop right.**

Shore hardness See **test, Shore hardness.**

short An imperfection that occurs, such as in a molded part, due to an incomplete fill. In molding, usually it is called *short shot.*

short-chain-branching See **molecular branched short-chain.**

shortcoming, plastic See **plastic product failure.**

short stopper See **polymerization, short stopper.**

shot In processes such as injection molding, compression molding, and rotational molding, the amount of material that is fed into the mold for each complete molding operation. See **screw plastic volume swept.**

shot capacity The maximum volume of material that a machine can process. See **injection-molding machine shot size.**

shot, cold See **extruder cold shot; injection-molding cold shot.**

shot peening Impacting the surface of the metal tooling with hard, small, round beads of materials to disrupt the surface flatness. It is used to stress relieve welds or imperfections in the metal or to improve the release of plastics during processing.

shot, short **1.** Insufficient plastic in the mold during injection molding to mold the desired part. **2.** In reinforced plastic insufficient plastic causing unacceptable surfaces due to poor plastic coverage. See **blow molding, injection; injection molding.**

shot size The amount of material that is used or dispensed at one time to manufacture a part. See **injection molding machine shot size.**

shows and conferences Trade shows and conferences pertaining to all aspects of plastics are conducted worldwide on a regular-basis. The Kunststoffe (which means plastic in German) eight-day show held in Dusseldorf, Germany, is the biggest plastic show in the world and exhibits equipment, materials, tooling, designs, and applications from materials to shipping. It is identified by the year of the show such as K'98 (Kunststoffe 1998). At K'98 there were over 2,600 exhibitors from over 49 countries with attendance of over 265,000 visitors. The PLASTICS USA five-day show in Chicago has over 12,000 worldwide attendees reviewing about 4,500 exhibits. Other shows include PLAST in Milan, Italy; EUROPLAST in Paris, France; INTERPLAS in Birmingham, England; and JapanPlas (JP) in Tokyo, Japan. See **Appendix D, Worldwide Plastics Industry Events.**

shredding See **communition.**

shrinkable fixture A form, usually of wood or metal, that ranges from flat to complex. Shape molded or thermoformed products may be held under light pressure during cooling to maintain the proper shape and dimensional accuracy of the product. This approach reduces the cycle time used during processing. Also called *shrinkage block* or *cooling fixture*.

shrinkable tubing, heat See **orientation and heat-shrinkability; tubing, heat-shrinkable.**

shrinkage The relative change in dimensions from those measured on a molded part after it is cold to those of the molded part usually after it is out of the mold for 24 h. Material behavior and processing conditions influence shrinkage. Fillers or reinforcements in materials are used to reduce shrinkage. With thermoset plastics there may be no shrinkage or a relatively insignificant amount. Many thermoplastics do shrink and require understanding of their shrinkage behaviors; some have very little shrinkage, and some have controllable or repeatable shrinkage. See **blow molding shrinkage; coefficient of linear thermal expansion; design, melt flow Cauchy-Riemann differential equation; design shrinkage; molding shrinkage; orientation and heat-shrinkability; plastic, low-profile; plastic properties; thermoplastic; thermoset plastic; tolerance and shrinkage; tolerance and warpage.**

shrinkage block jig A metal, wood, or plastic shaped block against which parts are held under light or no pressure while cooling to reduce warpage and distortion. See **extruder; injection; molding; thermoforming.**

shrinkage, concrete See **plastic-concrete composite.**

shrinkage differential Nonuniform material shrinkage in a part.

shrinkage, fabrication See **melting temperature.**

shrinkage index The numerical difference between the plastic part and shrinkage limits.

shrinkage pool An irregular, slightly depressed area on the surface of a part that is usually caused by uneven shrinkage before complete hardening is attained.

shrinkage, postmold Shrinkage that occurs after a part is removed from the mold. The cause could be incomplete or incorrect cure in mold or a material characteristic. See **design shrinkage; molding shrinkage; shrinkage.**

shrinkage, unrestrained A reduction in size of a material that occurs during its hardening or curing solidification process with no external forces applied that can inhibit such reduction.

shrink film See **orientation and heat-shrinkability; orientation, shrink-film.**

shrink fit See **ice, dry.**

shrink, low-profile See **plastic, low-profile.**

shrink mark See **sink mark.**

shrink wrap See **thermoforming, shrink wrapping.**

shutdown See **fabricating startup and shutdown.**

shuttle mark See **fabric, shuttle mark.**

shuttle mold See **clamping platen, shuttle.**

SI Abbreviation for the worldwide standard prepared by the International System of Units. SI is from the French name Le Système International d'Unités. This standard gives guidance for application of the modernized metric system developed and maintained by the Group Conference on Weights and Measures (CGPM for the official French name Conference Generale des Poids et Mesures). The SI abbreviations were adopted by the eleventh CGPM in 1960. See **Appendix B, Conversion Tables; decimal number system; measurement; meter; number marker.**

siamese blow See **blow molding, extruder-mold multiple, siamese.**

sieve See **screen; zeolite.**

sievert See **radiation dose equivalent.**

sigma See **deviation, standard, measurement.**

signature, printing See **printing signature.**

silane coupling agent A gas with a repulsive odor that solidifies at −200°C and decomposes in water. In a compound, it is used as a binder-finish on inorganic materials, such as glass, mineral fillers, metals, and metal oxides. On glass fibers it provides bonding of the glass to thermoset polyester reinforced plastics. It has been used since the early 1940s. See **additive, liquid; fiberglass binder/sizing coupling agent.**

silica (SiO_2) Natural (quartz, sand, flint, etc.) or synthetic white powders. The three commercial types are fumed (also called *pyrogenic* or *anhydrous silica*), precipitated (also called *hydrated silica*), and gel (also called *hydrogel, hydrous gel,* or *hydrated silica*). The fumed type is used as reinforcing fillers, thixotropic agents, and gel coating. The precipitated are used as flatting or matting agents in plastic and antiblocking agents in film and sheeting. See **glass composition; sodium silicate.**

silica coating See **barrier, glass-coating.**

silica gel See **desiccant drier.**

silicate A material that contains SiO_4 tetrahedra plus metallic salts. See **sodium silicate; vermiculate.**

silicon **1.** A nonmetallic element that occurs in quartz, sand, and many other common minerals. It melts at 1,410°C and is soluble in hydrofluoric acid and alkalies. It is extensively used in organic compounds and used as an intermediate for silicon-containing compounds. Silicon, which comprises about 28wt% of the earth's crust, almost never appears alone and is usually found in combination with other elements. Silicon is the basis for a family of extraordinary, synthetic materials, such as silicones. **2.** Electronic chip.

silicon-controlled rectifier See **electric motor drive; servo control-drive reliability.**

silicone (SI) A polymeric organic silicon compound that is used as plastics, oils, and greases and provides diverse performance properties. Also called *polyorganosiloxane*. See **mold-release agent.**

silicone adhesive See **adhesive, room-temperature cure.**

silicone elastomers Cross-linked silicone polymers of appropriate molecular weight. Since their introduction in 1940, they have been used in areas where retention of properties at both high and low temperatures is required, such as −50° to 315°C (−58° to 600°F). Many different silicone plastic compounds are used. Also called *silicone rubber*. See **ion-beam surface modification.**

silicone fluid additive A clear polydimethylsiloxane liquid that performs two basic functions. At low concentrations, they are used to process plastic additive improvers, increasing melt flow and providing self-release. At higher concentrations, they are used to form self-lubricating plastics for bearings and other mechanical applications. See **bearing; lubricant.**

silicone, medical Silicones in the form of elastomers, plastics, fluids, gels, and copolymers are used in pharmaceuticals, medical devices, and controlled drug-delivery systems to provide biosafety.

silicone molding compound Injection-molded solid and liquid silicone rubber that has high tear strength with high clarity and scorch resistance.

silicone plastic The backbone of SIs consists of alternating silicon and oxygen atoms. Pendant organic groups are attached to silicon atoms. They are usually made by hydrolyzing chlorosilanes, followed by polycondensation and cross-linking. Depending on the degree of cross-linking and the nature of the pendant groups, SIs can be liquid, elastomeric, or rigid plastics. Liquid silicones, with their very good antiadhesive properties, lubricity, and resistance to heat and chemicals, are used as release agents, molding compounds, surface coatings, laminating plastics, surfactants, and lubricants in plastics. See **adhesive, room-temperature cure.**

As lubricants they improve wear resistance. Silicone elastomers, or rubbers, have high resistance to compression set, flexibility, good dielectrics, weatherability, low flammability, good moisture barrier properties, and thermal stability. Their strength tends to be low. Optically clear grades are available. They are used in optical fiber coatings, electronic connector encapsulations, printed circuit board coatings, medical products, seals, and adhesives. Rigid SI offers good weatherability, flexibility, dirt release properties, and dimensional stability and are harder and stronger than SI elastomers. They are used in many different parts that require their special performance qualities. See **antifriction compound; methylsilicone plastic.**

silicone processing aid These aids provide consistency by entangling in the carrier, and distributing in the matrix in a uniform and permanent manner. For example, it is feasible to concentrate silicone at optimal points near the surfaces of both extrusion melt and finished parts. In finished parts, they elevate wear and abrasion resistance. See **wear.**

silicone, room temperature vulcanizing (RTV) Silicone that is vulcanized or cured at room temperature by a chemical reaction. RTV is commonly used for silicones and other thermoset elastomers. See **adhesive, room-temperature-cure.**

silicone rubber See **silicone plastic.**

silicone surfactant See **foamed polyurethane; surfactant.**

silk See **fiber, silk.**

silk-screen printing A method of transferring designs to fabric. Until 1940 the method was used on silk fabric; since that time screen printing has been used on predominantly plastic fiber fabrics. See **printing, screen.**

silo See **storage, silo.**

silver streaking See **splay mark.**

single-stage plastic See **A-B-C stages.**

sinking a mold See **mold-cavity hobbing.**

sink mark A shallow depression or dimple on the surface of a part that is due to the collapsing of the surface following local internal shrinkage after the melt solidifies. It frequently occurs on the part face that is opposite a face in which the section thickness increases, as in a rib. Also called *shrink mark* or *inverted blister*. See **defect.**

sintered metal See **metal impregnation.**

sintering **1.** Forming parts from fusible plastic powders. The process involves holding the pressed-powder (such as PTFE and nylon) part at a temperature just below its melting point for a prescribed time period based on the plastic used. Powdered particles are fused (sintered) together, but the mass as a whole does not melt. This solid-state diffusion results in the absence of a separate bonding phase. After being withdrawn, it is heated to a higher temperature to completely fuse the sintered coating. This process is accompanied by increase in properties such as strength, ductility, and usually density. See **diffusion; injection molding, nonplastic; molding, isotactic. 2.** See **coating, fluidized-bed; coating, sinter; extruder, Ballatini process; injection molding, nonplastic; injection molding, ultrahigh-molecular-weight polyethylene; laser sintering, selective; powder metallurgy.**

sisal See **fiber, sisal.**

size, industry See **plastic industry size.**

size, molecule See **Staudinger, Hermann.**

size, product See **product size.**

size-reduction equipment See **dicer; fine; granulator; pelletizing.**

sizing See **fiber sizing.**

sizing coupling agent See **fiberglass binder/sizing coupling agent; reinforced plastic ignition loss.**

skating rink See **ice, synthetic.**

skein See **fiber skein.**

skin **1.** The dense material that sometimes forms on the surface of foamed plastics. See **foam. 2.** A layer of dense material on the surfaces of the core that is used in a sandwich construction. See **sandwich construction.**

skin, synthetic The search goes on for long-lasting artificial skin to cover burned or otherwise damaged areas of a person. All types of approaches and materials are being studied, including plastics such as methacrylate mixtures, polypropylene over polyurethane foam, and porous polyurethane with polyester. See **medical applications.**

skiving See **film, skived.**

slate A finegrained metamorphic rock of varied composition that is used in powder form as a filler, such as in vinyl flooring.

sleeving **1.** A mold-bushing-type ejector. See **mold ejector. 2.** A braided, knitted, or woven fabric of cylinder shape. It is used in coating or reinforced-plastic structures. See **sewer rehabilitation.**

slenderness ratio **1.** The unsupported effective length of a uniform column divided by the least radius of gyration of the cross-sectional area. See **aspect ratio; reinforcement, whisker. 2.** The ratio of length to the least thickness of a panel.

slip A slurry containing chemical additives to control rheology. See **rheology.**

slip depressant See **antislip agent.**

slippage and tearing film/sheet See **extruder web tension control, slipping and tearing.**

slip-plane See **transparent slip-plane.**

slip promoter See **lubricant.**

slitting Cutting film or sheet into two or more sections using cutters such as heavy-duty razor blades. Adequate controls are necessary, particularly on speed rate. See **material, cutting burr-free.**

sliver See **fiber sliver, filament sliver.**

sludge **1.** A water-formed sedimentary deposit, such as waste water. See **waste. 2.** Undesirable residue in a rubber latex. See **latex.**

slug, cold See **molding cold slug.**

slurry A thin, watery suspension. See **water of saturation.**

slurry preforming See **preform process, water slurry.**

slush molding See **casting, slush molding; powder molding; rotational molding.**

smart plastic See **plastic, smart.**

smog Any contamination in the atmosphere, from fog to smoke. See **atmosphere; bloom.**

smoke The airborne solid and liquid particles and gases that evolve when a material undergoes pyrolysis, which is combustion. Some plastics burn with a relatively clean flame, while some give off heavy, dense smoke. Others give off noxious or hazardous gases. The composition of the smoke depends on the composition of the plastics and the many different additives and fillers used. See **fire; flame; flammability; phosphorous-base flame retardant.**

smoke emission When any material burns, some airborne combustion products are always emitted. In the case of a very clean coke fire, the emitted product may be invisible, tasteless, and dangerous carbon monoxide (CO) gas. A small amount of light, visible smoke may be best to ensure protection against CO. See **combustion; flame extinguished; flammability.**

smoke toxicity See **phosphorous-base flame retardant.**

snap-back forming See **thermoforming, snap-back.**

snap-fit See **design, snap-fit.**

S-N diagram See **fatigue S-N diagram.**

snow, artificial A plastic copolymer of butyl and isobutyl methacrylate often dispersed from an aerosol atomizing package. It is used in decorative window displays.

soap, metallic A product that is derived by reacting fatty acids with metals. It is widely used as a stabilizer for plastics.

social responsibility See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

societies See **shows and conferences; Appendix C, Worldwide Plastics Industry Associations; Appendix D, Worldwide Plastics Industry Events; World of Plastics Reviews.**

Society of Plastics Engineers See **World of Plastics Reviews: The Plastics Phenomenon.**

Society of Plastics Industry See **World of Plastics Reviews: SPI—The Industry's Voice.**

soda ash See **glass, plate.**
sodium carbonate See **glass composition.**
sodium hydroxide White deliquescent crystals that absorb carbon dioxide and water from air and is soluble in water, alcohol, and glycerol. It is used as a chemical intermediate and a detergent. Also called *caustic soda.*
sodium lime glass See **glass composition.**
sodium silicate (Na_2SiO_4) A gray-white powder that is soluble in alkalies and water, insoluble in alcohol and acids, and used to fireproof materials. Its largest single market is in laundry detergents. Other uses include production of derivative silicas, precipitated silicas, and aluminosilicas. Specialty applications include impregnating/sealing material such as in metal castings. Also called *silicate, water glass, liquid glass, silicate of soda, sodium metasilicate,* or *soluble glass.* See **metal impregnation; silica; silicate.**
sodium stearate A white powder that is used as a nontoxic stabilizer.
sodium treatment See **adhesive surface sodium treatment.**
softener A substance that is added to rubber and plastic compounds to facilitate the addition and dispersion of other solid compounding ingredients. It also enhances the processing properties. Softeners used as processing aids for the uncured rubber have also been referred to as *lubricants, plasticizers, tactifiers,* and *dispersing agents.* Numerous materials are used as softeners, including vegetable and petroleum oils, waxes, and various plastics (coumarone-indene, etc.). An important type is factice, which also provides some curing action when added to rubber. See **adhesive softener; factice.**
softening point (SP) The physical properties of softening points are determined by a variety of tests that include deflection temperature under load, Vicat softening point, and shear modulus as a function of temperature. See **test, deflection temperature under load; test, Vicat softening point; test, Martins temperature; thermomechanical analysis.**
softening temperature See **temperature, softening range.**
software See **computer software; control-system reliability; legal matter: software and patent; reliability.**
softwood See **wood classification.**
sol A colloidal solution that consists of a suitable dispersion media (which may be gas, liquid, or solid) and the colloidal substance (the disperse phase), which is distributed throughout the dispersion medium. See **gel; gel, zero-.**
solar absorptance The ratio of absorbed to incident radiant solar energy, which is equal to unity minus the reflectance and transmittance.
solar collector A device that collects solar energy. They are made of aluminized thermoplastic polyester film for reflectivity concentration, Fresnel lens, and prisms. See **Fresnel lens.**
solid Matter in its most highly concentrated form. The atoms or molecules of solids are much more closely packed than the atoms or molecules of gases or liquids and thus more resistant to deformation. See **molecule.**
solid geometry modeling See **modeling parametric.**
solder See **printed circuit board.**
solidification, plastic See **cure.**
solidification point An empirical constant that is defined as the temperature at which a liquid phase of a substance is in about equilibrium with a relatively small portion of the solid phase. See **plastic solidification.**
solid-phase pressure forming See **thermoforming, solid-phase pressure.**
solid-phase solution See **solution equilibrium with solid phase.**
solid sedimentation See **Stoke's law.**
solid-state biostabilizer See **waste biostabilizer.**
solid-state extrusion See **extruder, solid-state; fiber processing, solid-state extrusion.**
solid-state material See **engineering material.**
solid's volume See **calculus.**
solid waste See **British thermal unit; energy consumption; geomembrane; waste, municipal solid; waste, solid; waste, solid commercial; waste, solid, council; waste, solid food; waste, solid, management; waste, source reduction of.**
solid-waste volume reduction Decreasing the volume of solid waste through compaction or incineration. A 50 to 80% reduction is possible through compaction; 90 to 98% through incineration. See **compaction; incineration.**
solubility The ability or tendency of one substance to blend uniformly with another, solid in liquid, liquid in liquid, gas in liquid, gas in gas. The solubility of plastics differs both qualitatively and quantitatively from that of nonplastic solids. In general, one or more solvents exist for every plastic. If they are cross-linked or highly crystalline, they will not dissolve, but they may swell. Solubility is the maximum amount of solute that can be dissolved in a given quantity of solvent. See **plastic, water-soluble.**
solubility and molecular weight The solubility of a plastic in solvents is inverse to its molecular weight. The compatibility of plastics with plasticizers may similarly be inverse to the MW, which affects the latitude that is available to formulators of plasticized plastics. See **compatibility; molecular weight; plasticizer.**
solubility coefficient The volume of gas that can be dissolved by a unit volume of solvent at a fixed pressure and temperature.
solubility limit Maximum solute addition without supersaturation.
solubility parameter The capacity of a material to be dissolved in another material, such as a plastic in a solvent. It represents the cohesive energy of molecules in a material and determines the magnitude of the heat of mixing two materials in given concentrations. The magnitude and sign of the heat of mixing determine the sign of the free energy

of mixing. The solution occurs when the sign of the free energy of mixing is negative. See **polarity.**

solubility product The equilibrium constant for the solution process of a sparingly soluble salt.

soluble Capable of being dissolved in a liquid. See **immiscible.**

soluble core molding Soluble-core technology (SCT) is also called *soluble fusible metal-core technology* (FMCT), *fusible-core, lost-core,* and *lost-wax techniques.* In this process, a core—usually molded of a low-melting alloy (eutectic mixture) but also water-soluble thermoplastics or wax formulations—is inserted into a mold such as an injection-molding mold. This core can be of thin-wall or solid construction. If the part design permits, the core can be supported by the mold halves or spider-type pin supports that are used to float it within the cavity; during plastic molding, the pins will melt. After the plastic solidifies, the core is removed by applying a temperature below the melting point of the plastic. Core material is poured through an existing opening or will require drilling a hole in the plastic. This technique is similar to the lost-wax molding process used by the ancient Egyptians to fabricate jewelry. The lost-wax process was used to bag mold the reinforced-plastic sandwich construction of the 1944 all-plastic airplane. See **aircraft; automotive intake manifold; casting, investment; eutectic mixture; extruder, liquid-curing-medium; injection molding, soluble core; metal, white; reinforced-plastic molding, lost-wax; reinforced plastic soluble core molding; wax, soluble core.**

soluble, non- See **immiscible.**

solute The material that dissolves in a solvent; the component of a solution that is usually present in the smaller amount. See **colligative property; heat of solution; molar solution.**

solution A homogeneous mixture of two or more substances, such as liquids, solids in liquids, gases in liquids, gases in solids, or solids in solids.

solution casting See **film, cast.**

solution, colloidal A liquid colloidal dispersion is often called a *solution,* but since colloidal particles are larger than molecules, it is incorrect to call such dispersions *solutions.* See **chemical introfier; colloidal ultrafiltration; lyophilic; molecule.**

solution, dilute A solution that contains a small amount of solute. See **viscosity, dilute-solution.**

solution equilibrium with solid phase A solution that will not dissolve any more solid material.

solution, heat of See **heat of solution.**

solution, ideal A solution that obeys Raoult's law at all concentrations. See **Raoult's law.**

solution, ionizing See **molecule, polar.**

solution, solid A homogeneous mixture of two or more components, in a solid state, retaining substantially the structure of one of the components.

solution, plastic See **liquid crystal, lyotropic.**

solution, precipitating See **sequestering agent.**

solution processing See **liquid crystal, lyotropic; prepreg solution process.**

solution, saturated A solution in which dissolved solute and undissolved solute are in dynamic equilibrium. See **dynamic.**

solution spinning process See **fiber processing, gel-spinning; fiber processing, solution-spinning.**

solution, unsaturated A solution that contains less dissolved solute than it has the capacity to dissolve.

solution viscosity Viscosity is measured by the flow rate through a capillary tube. Temperature and concentration are carefully controlled.

solution volumetric analysis This analysis is completed by measuring the volume of a solution of established concentration that is needed to react completely with the substance being determined. It is customary to divide the reactions of volumetric analysis into four groups: (1) neutralization methods (acidimetry and alkalimetry), (2) oxidation and reduction (redox) methods, (3) precipitation methods, and (4) complex formulation (ion combination) methods. See **ion; redox.**

solvating action A complex ion that is formed by the chemical or physical combination of a solute ion or molecule with a solvent molecule. It is also a substance, as a hydrate, that contains such ions. See **organosol diluent; plastisol.**

solvation See **plastic solvation.**

solvency Solvent action or strength of the solvent action.

solvent A substance that is used to dissolve another substance. For example, a dissolving liquid can be used to thin a plastic that may be too thick to use during certain processes, such as roll coating and impregnation of substrates. After processing the solvent is driven off by apparatus such as air drying or heating. They should be recovered through methods such as condensation for proper disposal or reuse. The solubility properties of a solvent vary. Those with small, compact molecules generally dissolve plastics more rapidly than solvents with larger molecules, although the molecular structure of the thermoplastic and the surface condition of the parts also affect solubility. See **acetone; butyl acetate; butyl diglycol carbonate; butyl ether; butyrolactone; carbon disulfide; dichloroethylene; ethyl benzene; percolation; thinner; xylene plastic.** Solvents have different classifications, such as alcohol, ketone, ester, glycol ester, ether, hydrocarbon, and chlorinated compound. Solvents are used in the pretreatment of certain plastic parts prior to decoration or finishing. See **decorating pretreatment.**

solvent bonding See **adhesive, solvent; plasma are treatment.**

solvent-borne coating A solution of plastics and additives. After application, they dry by solvent evaporation and may be cross-linked or cured during baking. A clear solvent-borne coating is called a *lacquer.* See **coating; lacquer.**

solvent cement See **adhesive solvent cement.**

solvent content See **prepreg volatile content.**
solvent cracking An alternate name for *environmental stress cracking.* See **environmental stress cracking.**
solvent curing elastomer See **adhesive contact cement.**
solvent degreasing See **cleaning, solvent.**
solvent, epoxy See **butyrolactone.**
solvent extraction See **degradation, swelling, extraction, and random.**
solvent finish See **finish system, reduced-solvent.**
solvent fractionation The differential dissolving of a mixed plastic stream in selected solvents for later separation and recovery by plastic type. Also called *polymer dissolution.*
solvent, hydrocarbon A solvent that is used as a diluent in many plastic systems and plays an important role in coating formulations, in which it is used as an active solvent.
solvent joint See **adhesive, solvent.**
solvent, latent A thinner that dissolves constituents of surface-coating materials only when activated by mixing with a true solvent.
solventless coating See **powder coating.**
solvent, low-flammability See **chlorinated compound solvent.**
solvent, nonpolar A solvent that consists mainly of the aliphatic and aromatic hydrocarbons and contains only carbon and hydrogen.
solvent permeation See **percolation.**
solvent, polar The formation of emulsions and the action of detergents. See **molecule, polar.**
solvent resistance A measure of the ability of a plastic to resist deterioration in the presence of a solvent. See **pigment, metal chelate.**
solvent stress cracking See **environmental stress cracking.**
solvent stripping See **extruder, reactive-processing.**
solvent tolerance In the formation of paints and varnishes, the extent to which dilution of a concentrate solution of plastic or oil with a solvent is possible before precipitation or clouding occurs. It is usually expressed as the percentage plastic of the solution at the point where the onset of cloudiness is first evident. See **paint; tolerance.**
solvent welding See **solvent bonding.**
sonic nozzle A pneumatic or vibratory atomizer in which energy is imparted at frequencies below 20 kHz to the liquid.
sonic pulse, transverse A sonic pulse in which the deformation is at right angles to the direction of propagation.
solvent, reduce See **finish system, reduced-solvent.**
sorbent A liquid or solid medium in or on which materials are retained by absorption or adsorption. See **absorption; adsorption; elute.**
sorption The process of taking up or holding a material by absorption or adsorption. *Sorption* is a generalized term that is used to describe the penetration and dispersal of the molecules of an ambient gas, vapor, or liquid onto or throughout a plastic solid to form a mixture. The sorption process can be described as the distribution of the mobile component between two or more phases to include absorption, adsorption, incorporation into microcavities, and other modes of mixing. The phenomena of sorption by plastics are manifested in a variety of ways. See **absorption; barrier, vapor.**
sound absorption **1.** The process of dissipating sound energy. **2.** The property possessed by materials, objects, and structures, such as rooms that absorb sound waves. See **absorption; acoustical board. 3.** The metric unit sabin is a measure of sound absorption in a specified frequency band—the measure of the magnitude of the absorptive property of a material or object.
sound attenuation The reduction of the intensity of sound as it travels from the source to a receiving station.
sound-deadening Common plastics when modified with the right mix of additives can substantially reduce noise levels or sound transmissions by absorption due to acoustic, vibration, and impact sources. See **flocking.**
soybean-filled plastic See **plastic, soybean-based.**
soyo bean flour An organic noncellulose filler.
space charge See **dielectric space charge.**
spacer See **mold chase.**
spalling **1.** The type of wear that is caused by repetitive contact stress. It is a form of stress fatigue. Also called *pitting erosion.* See **fatigue stress, mean; pit; wear. 2.** The cracking, breaking, or splintering of material due to thermal stresses.
spanishing See **embossing spanishing.**
spark See **static problem.**
spark erosion See **electroerosive cutting and sinking; film perforating; mold-cavity hobbing.**
spark test See **test, electrical-spark coating.**
special control See **motion control system.**
specie A particular kind of atom, atomic nucleus, ion, or molecule.
specification A document that includes all the requirements a material or product has to meet for it to be approved. Requirements include dimensions, properties (physical, mechanical, chemical, environmental, etc.), and appearance. Many organizations are involved in preparing or coordinating specifications and standards. They include ASTM, BSI, CSA, DIN, DOT, ISO, JIS, UL, ACS, ANSI, ASCE, ASM, ASME, EIA, FDA, IEEE, NEMA, NFPA, NIST, PLASTIC, SAE, and TAPPI. See **Appendix A, List of Abbreviations; extruder specification; material received, checking; quality system regulation; standard; test data and uniform standards; testing.**
specification, limited-coordination A specification or standard that has not been fully coordinated and accepted by all interested parties. It generally applies to military agency documents.
specification qualification See **qualified products list.**

specific gravity (s.g.) The weight of a volume of any material compared to the weight of an equal volume of water. The temperatures of both are specified and usually equal. Examples of s.g. for a few materials are 2.7 aluminum, 8.5 brass, 1.27 to 1.63 cellulose acetate, 8.8 copper, 2.4 to 5.9 glass, 7.0 to 7.9 iron, 11.3 lead, 2.6 to 2.8 marble, 1.18 PMMA, 1.25 to 2.1 phenolic, 0.9 to 1.1 general plastic, 1.05 to 1.07 polystyrene, 7.6 to 7.8 steel, 1.0 water, 0.65 to 1.23 hard wood, 0.38 to 0.92 soft wood, and 7.1 zinc. See **mass; melt density; water, property; weight; weight, material; wood specific gravity.**
specific gravity, apparent The ratio of the weight in air of a given volume of the impregnable portion of a permeable material (that is, the solid matter including its permeable pores or voids) to the weight in air of an equal volume of distilled water at a stated temperature. See **void.**
specific gravity, bulk The weight in air of a given volume of a permeable material (including both permeable and impermeable voids normal to the material) to the weight in air of an equal volume of distilled water at a stated temperature. See **void.**
specific gravity conversion To convert to ounce per cubic inch, multiply the s.g. by 0.5778. To convert from grams to cubic inch, multiply by 16.387. To determine cost per cubic inch, multiply cost per pound by s.g. and also multiply by 0.03163. See **cost per volume of plastic; volume-to-weight conversion; weight-to-volume conversion.**
specific heat See **heat capacity.**
specific inductive capacity See **dielectric dissipation factor.**
specific insulation resistance See **electrical-volume resistivity.**
specimen A material that is appropriately shaped and prepared (temperature, time, etc.) so that it is ready to be used for testing. See **directional property; testing.**
specimen, dumbbell A flat test specimen having a narrow straight central portion of essentially uniform cross-section with enlarged ends. It is used principally with rubber or elastomer plastic materials.
speck, black A defect that appears in or on plastics as a small dark spot after processing. Incoming plastic material needs to be examined for black spots. There are ways to eliminate them that include specifications that can set limits on amount and size.
Spectra Allied Signal's trade name for its ultrathin polyethylene fibers that are about 10 times stronger than steel. See **fiber processing, gel-spinning; fiber processing, solution-spinning.**
spectrochemical buffer A substance that by its addition or presence tends to minimize the effects of one or more of the elements on the emission of other elements.
spectrograph, x-ray An x-ray spectrometer that is equipped with photographic or other recording apparatus. One application is fluorescence analysis.
spectrograph, x-ray fluorescence (XRF) In plastics, XRF analysis can be used to quantify various pigments, flame-resistance, or ultraviolet stabilizer additives that are based on elements, such as titanium, copper, zinc, bromide, or phosphorus. XRF simultaneously measures all the elements in 50 s or less. Samples are irradiated by x-rays that cause electrons in the atoms of the sample to jump to a higher energy level. On dropping back to the original energy level, the electrons emit x-rays of precise energy and wavelength that are characteristic of a particular element. This is the process of fluorescence. See **fluorescent; processing via fluorescence spectroscopy.**
spectrometer See **infrared spectroscopy.**
spectrometer, mass (MS) A method of substance structure analysis that is based on sending an ionized beam of substance molecules or molecular fragments through a magnetic field to achieve a separation depending on the mass-electric charge ratio of the particles. It is capable of measuring the respective ion currents. It is used in measurement of low-molecular-weight polymers. See **chemistry, analytical; gas analysis, residual.**
spectrometer, ultraviolet A device that produces a spectrum of UV light and is provided with a calibrated scale for measuring wavelength. This method of analysis is similar to infrared spectrometry except that the spectrum is obtained with UV light. It is sometimes less sensitive than the IR method analysis but is useful for detecting some plasticizers and antioxidants. It provides a calibrated scale for measurement of wavelength. See **infrared spectroscopy.**
spectrometer, x-ray See **x-ray spectroscopy.**
spectrometry, electrospray mass See **electrospray mass spectrometry.**
spectrometry, mass (MS) A technique for the molecular structural analysis of degradable organic plastics in which a small sample (micrograms) is ionized by electron impact and volatilized ions are separated according to their mass/charge ratios by passing them through electrostatic or magnetic fields. The resultant mass spectrum shows the variation in intensity. For plastics, the main difficulty, for other than low-molecular-weight plastics, is that they are not volatile. See **molecular structure.**
spectrophotometer A device that does color matching, sometimes with computer programs. See **analytical instrument; color evaluation; colorimeter; color matching.**
spectroscopic analysis A method of analyzing plastics that includes atomic absorption, nuclear magnetic resonance, infrared, Raman, ultraviolet, luminescence, and electron spectroscopy; gas chromatography; mass spectrometry; and electron spin resonance. See **chromatography; test, chemical.**
spectroscopy The study of using an instrument for dispersing radiation. It allows visual observation of the radiation energy emission or absorption by a substance in any wavelength of the electromagnetic spectrum in response to an external energy source. See **dielectrometry; electron spin resonance spectroscopy; emission spec-**

troscopy; infrared spectroscopy luminescent pigment; photochemical hole-burning spectroscopy; processing via fluorescence spectroscopy; resonance; molecular spectroscopy; optical image spectroscopy; spectrograph, x-ray fluorescence; test analysis, micromechanical; testing; thermal analysis.

spectroscopy, absorption A technique of instrumental analysis that involves measurement of the absorption of radiant energy by a substance as a function of the energy incident on it. Either absorption or emission may be examined. If the emitted energy is studied, the term *resonance fluorescence* is used.

spectroscopy, atomic absorption (AAS) A very sensitive analytical method that is available for the determination of metallic elements in solution. The element of interest in the sample is not excited, but it is merely disassociated from its chemical bonds and placed into an unexcited, unionized ground state. In this state, it is capable of absorbing characteristic radiation of the proper wavelength, which is generated in a source lamp containing the sample element as an anode. The usual method of disassociation is by burning the sample in a flame of the appropriate gas or gases.

spectroscopy, dielectric relaxation The study of the frequency dependence of the electrical permittivity or dielectric constant. See **dielectrometry; test, dielectric.**

spectroscopy, Fourier's transfer infrared An analytical method that is used to automatically advance forms of spectroscopic analysis such as infrared and nuclear magnetic resonance spectroscopy. It is widely used for additive characterization due to its short measurement cycle and the wealth of molecular information that is provided by the fundamental absorption frequencies found in the mid-IR regions of most plastics. See **absorption; additive; infrared; injection-molding infrared temperature control; molecular structure.**

spectroscopy, microwave A type of absorption spectroscopy that is used in instrumental chemical analysis that involves the use of that portion of the electromagnetic spectrum having wavelengths in the range of far infrared and radio frequencies between 1 mm to 30 cm. See **chemical analysis.**

spectroscopy, nuclear magnetic resonance (NMR) The measuring of radio-frequency-induced transmissions between magnetic energy levels of atomic nuclei. It is a powerful method for elucidating chemical structures, such as by characterizing material by the number, nature, and environment of the hydrogen atoms present in a molecule. This technique is used to solve problems of crystallinity, polymer configuration, and chain structure. See **chemistry, analytical; electron spin resonance spectroscopy; thermal analysis.**

spectroscopy position-annihilation (PAS) A method of studying thin film properties.

spectroscopy, Raman A method of measuring the molecular motions that cause Raman scattering of ultraviolet light and that also produce infrared absorption bands. Macromolecular motions that are uniquely accessible to Raman analysis include accordionlike stretching of chains in the lamellar regions. Lamellae are sheetlike regions of crystalline order that coexist in many plastics with amorphous regions. Raman spectroscopy thus is important in determining maximum theoretical extensions to which plastics may be drawn when high-tensile modulus fibers are made. See **lamella; light scattering.**

spectrum **1.** The ordered arrangement of electromagnetic radiation according to wavelength, wave number, or frequency. **2.** The radiant energy emitted by a substance as a characteristic band of wavelengths by which it can be identified. **3.** The complete range of colors in the rainbow from short wavelengths (blue) to long wavelengths (red).

specular transmission The transmission of light across clear and colorless test specimens within a very narrow range. The T_s is related to specimen thickness. Expressions such as transparency, clarity, see-through clarity, and image resolution are used in this context. See **light transmission.**

spew See **die parting line; mold-parting line.**

sphere, hollow micro- See **microsphere.**

sphere, solid See **glass sphere, solid.**

Spheripol process See **polymerization, Spheripol process.**

spherulite In plastics, a rounded aggregate of radiating lamellar crystals with amorphous material between the crystals. Spherulites exist in most crystalline plastics and usually impinge on one another to form polyhedrons. The range in size from a few tenths of a micron in diameter to several millimeters. See **annealing; crystalline plastic; transcrystalline growth.**

spider See **die spider; mold ejector; mold gate, spider.**

spider line See **die spider line.**

spin axis The axis of rotation of a product, such as a wheel, or a process, such as rotational molding or filament winding.

spinneret See **fiber spinneret.**

spinning See **fiber processing; spinning.**

spinning flash See **fabric, nonwoven flash-spun.**

spin trimming A method for removing flash in which a container or other circular product is revolved into and against a fixed knife. See **deflashing; molding flash.**

Spirex software See **melt flow analysis; screw inspection; training.**

SPI/SPE Mold Standard Finish See **surface finish.**

splay mark Fanlike or streaking on the surface of fabricated plastic parts. Causes include moisture in the plastic material, thermal degradation of plastic material, relatively cold plastic on mold or die surface due to too fast an operation (called jetting), injection mold gate restriction, and foam molding. Also called *silver streak.* See **injection molding, jetting; injection molding splay; injection molding venting.**

spline To prepare a surface to its desired contour by working a paste material with a flat-edge tool. The procedure is similar to surfacing (screening) of concrete; the same tools are used. See **surface finish.**

sponge, cellulose See **cellulose sponge; foam.**

spontaneous ignition See **combustion, autoignition point.**

spool See **fiber spool; roving ball.**

spray, air atomization In air spraying, the liquid is atomized by a stream of air. See **air atomization.**

spray, airless Forcing a paint through a small nozzle at a sufficiently high velocity, or impinging the paint stream against a part, to cause a sudden change in flow direction. In either case, the fluid stream disintegrates into small particles. The degree of atomization is rather poor when compared to air atomization; however, it is more energy efficient, requires less paint, and the transfer efficiency is much better.

spray-and-wipe See **decorating, fill-and-wipe.**

spray assist See **electrostatic assist.**

spray, centrifugal Spraying the liquid stream against a rotating disk or bell-shaped device with electrostatic assist. Such sprayers are more energy-efficient than air or airless sprayers. See **electrostatic assist.**

spray coating A method of applying liquid that is usually accomplished on continuous webs, belts, or suspension continuous moving lines. Spray coating is used in different processing configurations. For example, a reciprocating spray nozzle, moving laterally, deposits the coating on products that are on a moving belt.

spray coating, thermal (TSC) A method of coating, with or without mask, materials that include pure metals, metal alloys, ceramics, and low-temperature plastics. Unlike plating operations, TSCs can be applied to almost any substrate that includes plastics, metals, or ceramics. Most coatings are 0.001 to 0.030 in. (0.003 to 0.08 cm) thick, depending on the material used. Some coating materials have no thickness limitations. These smooth coatings can meet a tolerance of ± 0.0005 in. with general thickness to ± 0.001 in. The system includes an oxy-fuel combustion/flame sprayer, twin wire electric arc, plasma spray (non-transferred arc), plasma arc (transfer), high-velocity oxy-fuel (HVOF), and detonation gun. TSC is very cost effective. See **thermal spray coating.**

spray-coating transfer efficiency The percentage of a sprayed coating that lands on its target. For example, air atomization is at 35%, air atomization with electrostatic assist at 55%, airless atomization at 50%, airless atomization with electrostatic assist at 70%, and disk or bell atomization with electrostatic assist at 90%. Most sprayers are centrifugal sprayers with electrostatic assist, and they reach a TE of 90%. See **electrostatic assist.**

spray degreasing See **cleaning, solvent.**

spray, flame See **coating, flame-spraying.**

spray, mass spectrometry electro- See **electrospray mass spectrometry.**

spray metal See **mold material, sprayed-metal.**

spray-paint coating This method is especially attractive for parts that have been assembled and have irregular shapes or curved surfaces. The material applied is generally in the form of paint, which is a combination of plastic, solvent, diluent, additive, and pigment. It is usually applied at room temperature, but hot plastic or a plastic completely dissolved in a solvent can also be used. Many different types of spray guns are available. Typical classifications are the method of atomization (air, airless, rotary, or electrostatic) and the method of deposition assist (electrostatic or non-electrostatic). Compressed air spray painting was first reported during 1898 as being applied to 400 railroad cars per week. See **air atomization; coating, air-atomization; electrostatic assist; paint.**

spray-paint coating mask Masks are used to provide sharp lines of demarcation, particularly when more than one color is used. They are generally made from electroformed nickel, but sometimes paper, elastomer, and plastic are used for short runs. For masks to work properly, the surface of the plastic they cover has to fit within close tolerances, otherwise leakage or blow-outs will occur.

spray paint, spray and wipe See **decorating, fill-and-wipe.**

spray, reinforced plastic See **reinforced-plastic spray-up.**

spray, silver See **plating, silver-spray.**

spray-up gun The most common are identified as external and internal mixers. Some have solvent and paint flushing systems. They vary in the number of spray nozzles used that provide laminar, turbulent, or distributive (combining laminar and turbulent flows) mixing. They use different approaches to mixing plastic, catalyst, additive, or whatever paint system is to be compounded in the mixing head.

spreader A streamlined metal block that is placed in the path of a melt in the heating cylinder of extruders or injection-molding machines to aid in heating the melt by providing more contact with the heating areas. The path of the melt flow in a plasticator spreads melt into thin layers, thus forcing it into intimate contact with the barrel heating areas. Also called *torpedo.* See **bank; die-head mandrel; doctor blade; doctor roll; injection-molding machine, ram; injection-molding melt extractor; screw torpedo.**

spreader roll, film See **doctor roll; extruder roll, spreader/expander.**

spring See **design, spring.**

sprue See **mold sprue.**

spur The piece of plastic that is formed in the sprue of an injection or transfer molded part.

squeegee A soft, flexible roll or blade that is used in wiping operations, such as screen printing and paint wipe and dry.

squeeze molding See **reinforced-plastic squeeze molding.**

S-S curve See **stress-strain curve.**

stability Resistance to degradation or deterioration from any of a number of conditions such as heat, moisture, chemical exposure, prolonged storage, or ultraviolet light. Also called *durability*.

stabilization **1.** The treatment to which plastics are subjected in an effort to control or adjust effectively the deteriorative physiochemical reactions at work during manufacture, compounding, processing, or use. **2.** In carbon and graphite fiber forming, the process used to render the fiber precursor infusible to carbonization. See **fiber, graphite.** **3.** Rendering waste relatively inert, uniform, biologically inactive, nuisance-free, or harmless. See **waste.**

stabilizer An agent or material that is present in or added to practically all plastics to improve their performance. Stabilizers inhibit chemical reactions that bring about undesirable chemical degradation. For example, stabilizers in vinyls and polyolefins help them maintain properties at or near their initial values during storage, fabrication of parts, and service life of the parts. Some impede or retard degradation, usually due to heat or ultraviolet radiation. The viscosity of certain plastics has to be changed prior to processing. In some plastics, particularly elastomers, stabilizers assist in maintaining the physical and chemical properties during processing and in service. There are three major groups: metallic (barium stearate, cadmium stearate, etc.), organometallic (dibutyl tin dilaurate, etc.), and organic (epoxies, etc.). See **acid acceptor; additive; anticoagulant; antioxidant agent; antiozonant agent; barium stearate; butyl diglycol carbonate; butyl stearate; calcium sulfide; carnauba wax; dicyandiamide; emulsifier agent; epoxide stabilizer; filler; heat; inhibitor; light stabilizer; liquifier; lubricant; optical brighten agent; oxidizing agent; plastic material; processing stabilizer; rodent-resistant additive; silicon; slip; ultraviolet absorber; zinc stearate type.**

stabilizer, internal An agent that is incorporated in a plastic during polymerization as opposed to a stabilizer that is added during compounding.

stadium See **grass, synthetic.**

staging See **thermoset plastic staging.**

stain, antioxidant non- An additive that does not impart color to the plastic that it is protecting, either initially or after degradation. Most thiophenols and peroxide destroyers are nonstaining. See **antioxidant agent.**

stain, color See **color-dispersion staining.**

stain, contact The discoloration of a product by another material or product in the area directly touching it.

stain-resistant agent A substance that has the ability to resist staining plastics. Different agents are used for the different plastics. Factors that cause stains include spilled food, lipstick, waxing compounds, grease deposits, and nail polish. See **antioxidant agent.**

staking The forming of a head on a thermoplastic stud by cold flowing or melting of the plastic. The stud protrudes through a hole in the parts being joined, and staking the stud mechanically locks the two or more parts together. Cold staking or heading uses high pressures, such as 6,000 psi (41 MPa), to induce cold flow of the TP. Because high stresses are created, only the more malleable TPs are used. With heat staking low pressure is used to compress and form the stud head. A high-speed method is *thermostaking,* also called *thermopneumatic staking.* A heated, hollow tool delivers a low volume of superheated air to the stud, followed by a low-pressure cold-stake probe. Ultrasonic staking is also used. See **adhesive; bonding; cold heading; joining, rivet; sealing, ultrasonic; welding, ultrasonic.**

stalk The European term for *sprue.* See **mold sprue.**

stamping In the stamping process, a sheet of thermoplastic (unreinforced or reinforced) is precut to the required size. The precut sheet is heated to a temperature that softens the particular plastics used. On being heated it is quickly stamped in a press and formed to the shape of the forming tools. Also called *cold stamping.* See **forming; press; reinforced plastic; thermoforming, solid-phase pressure.**

stamping, hot An engraving operation for marking plastics in which a roll leaf is stamped with heated metal dies onto the surface of the plastics. Another method is by means of felt cover rolls where ink is applied to type and by means of heat and pressure, type is impressed. See **decorating; printing, roll-on.**

stamping measurement See **pressure-detecting film.**

stamping, reinforced thermoplastic A continuous extruded thermoplastic sheet is pressure laminated with typical 40wt% glass fibers (chopped or continuous) for fabricating by stamping. Sheet is cut into required sizes, dielectrically heated to about 260° to 316°C (500° to 600°F depending on the plastic used, such as nylon or PP) for subsequent charging to the mold. See **directional property; extruder sheet; laminate; reinforced plastic.**

stamping, roll leaf See **printing, roll-leaf.**

stamping, rubber See **forming, rubber-pad.**

stamping, thermographic transfer See **printing, thermographic transfer.**

standard A model or rule that has been established by authority, custom, or agreement to govern the procedures and practices of engineers and its applications. See **material received, checking; National Institute of Standards and Technology; recommended practice; test data and uniform standards.**

standard data See **test data and uniform standards.**

standard depth of penetration See **electrical eddy current, standard depth of penetration.**

standard error See **error.**

standard industrial classification (SIC) A system that is published by the U.S. Department of Commerce and that classifies all manufacturing industries and services produced in the United States (transportation, communication, electronic, plastic, etc.). The digital numbering system follows a pattern that provides detailed input and output information data. Basically the I/O program determines what each of about 470 product-level industries consumes from each of the other industries. The manufacturing segments of the plastics industry are in the major group numbers 28 (chemicals and allied products) and 30 (rubber and miscellaneous plastics products) in four-digit listings, such as the SIC 2821 (plastics materials), SIC 3081 (unsupported plastics film and sheet), SIC 3084 (plastics bottles), SIC 3086 (plastics foam products), SIC 3088 (plastics plumbing fixtures), and so on. See **fabricating process type; plastic industry.**

standard, internal A compound of known behavior that is added to a sample to facilitate the analysis.

standard, medical See **electronic standard, international.**

starch degradable Biological degradation, such as it occurs by compost. This expensive approach is possible only if the plastic has molecular structures that can be broken down by microorganisms. The search for inexpensive degradables led to the investigation of natural polymers, such as cellulose or starch. See **biodegradable waste; biodegradable versus photodegradable; compost; waste.**

starch-oil binder See **fiberglass binder/sizing coupling agent.**

startup See **fabricating startup and shutdown.**

starved area A localized area of insufficient plastic that is usually identified by low gloss, dry spots, or additives/reinforcements visible on the surface. See **defect; reinforced plastic.**

starve feeding See **material starve feeding.**

static Usually a disturbing effect that is brought about by electrical devices. See **antistatic agent; electromagnetic interference; electrostatic; extruder sheet antistatic bath.**

static charge The electrical charge that is produced by the relative motion of a nonconducting material over a nonconducting plastic material. Charge separation is due to mechanical motion. This charge is a potential problem during the processing of plastics. See **electrostatic charge.**

static coefficient of friction See **coefficient of friction, static.**

static conductivity See **electrical conductivity; test, conductivity.**

static decay rate The measured rate of how quickly a static charge is dissipated from a material under controlled conditions (Federal Test Method 101, Method 4046). See **test, conductivity.**

static, destaticization The process of reducing the accumulation of static electricity on plastics, usually with the objective of minimizing dust pick-up or sparking.

static eliminator A mechanical device or additive that is used for removing electrical static charge. Creating an ionizing atmosphere in close proximity to the surface neutralizes the static charges. Types of eliminators include ionizing blowers, static bars (in an extrusion film line, etc.), and radioactive elements. An example of a low-cost approach involves unbraiding strands of copper wire with fine threads, letting them slide on the film or sheet being processed, and attaching the other ends to the metal machine. See **extruder-sheet antistatic bath; plastic, electrically conductive; static neutralizer.**

static load An imposed stationary force with constant magnitude, sense, and direction.

static load measurement See **stress-strain measurement.**

static mixer A device that achieves a homogeneous mix by flowing one or more plastic streams through geometric patterns formed by mechanical elements in a tube or barrel. The mixers contain a series of passive elements placed in a flow channel. These elements cause the plastic compound to subdivide and recombine to increase the homogeneity and temperature uniformity of the melt. There are no moving parts, and only a small increase in energy is needed to overcome the resistance of the mechanical baffles. These mixers are located at the end of the screw plasticator, such as an injection-molding machine or before the screen changer or die of an extruder. In an extruder if a gear pump is used, the static mixer is located between the screw and gear pump. They can be used to mix different plastics and plastics with component ingredients, such as color and additives. Also called a *motionless mixer.* See **extruder static mixer; mixer; screw, mixing and melting.**

static modulus See **modulus, static.**

static neutralizer An attachment in a process, such as an extruder film line, that removes static electricity from the substrate (film, etc.) to avoid trouble with wrap-up. See **static eliminator.**

static problem Static accumulation and electrostatic discharge (ESD) are controlled or eliminated by adjusting electrical characteristics of materials or their immediate environment. Conductive plastics prevent static accumulation from reaching dangerous levels by reducing a material's electrical resistance. This allows static to dissipate slowly and continuously rather than accumulating and discharging rapidly, which could cause a spark. See **electrical conductivity; electromagnetic interference.**

statistic **1.** A piece of quantitative analysis data (data collection) that pertains to any subject or group, especially when the data are systematically gathered and collated. **2.** The science that deals with the collection, tabulation, analysis, interpretation, and presentation of quantitative data. See **computers and statistics; Japanese workmanship; probability; quality; quantitative analysis reliability.**

statistical assessment A fabricator's assessment of its use of SPC tools should consist of a formal, documented examination of current statistical practices and procedures and an evaluation of future plans for improvements of the company's quality control. This assessment should go beyond the compliance-oriented approach that is commonly seen in quality audits. Fabricators should set up key objectives for their assessment of good statistical practices by

(1) determining the current state of compliance regulations, (2) determining impediments to compliance, (3) raising awareness of regulations, (4) measuring improvements over time, (5) discovering the best statistical practices in use throughout the company and sharing them with the rest of the company, and (6) providing advice on incorporating statistical tools into the quality improvement system. See **mixing evaluation; plastic material selection; zero defect.**

statistical benefit Using statistical methods in the design of experiments and data analysis allows designers, compound formulators, and others to attain benefits that would otherwise be considered unachievable. Benefits include a 20 to 70% reduction in problem-solving time; a minimum 50% reduction in costs due to testing, machine processing time, labor, and materials; and a 200 to 300% increase in value, quality, and reliability of the information generated. See **problems and solutions; quality; reliability; testing and quality control.**

statistical data collection Data may be collected directly by observation or indirectly through written or verbal questions. The latter technique is used extensively by market-research personnel and public-opinion pollsters. Data that are collected for quality-control purposes are obtained by direct observation and are classified as either variables or attributes. Variables are those quality characteristics that are measurable, such as a weight measurement in grams. Attributes are those quality characteristics that are classified as either conforming or not conforming to specifications. In other words, attributes are either good or bad, while variables indicate degree of goodness or badness. See **mean; risk, acceptable; risk assessment; test data and uniform standards.**

statistical effect The response of the process to a change in factor level from low to high.

statistical equivalent loading system The St. Venant's principle states that the stress and defection of a part (handle, gear, etc.) at points sufficiently distant from points of load application may be determined on the basis of a statistical loading system. See **deformation; stress; structure.**

statistical estimation A procedure for making a statistical inference about the numerical values of one or more unknown population parameters from the observed values in a sample. See **probability.**

statistical factor A process or recipe variable that can be controlled independently, such as temperature and the ratio of filler to plastic.

statistical forecasting Procedures that utilize mathematical formulas to develop forecasts for sales, R&D, supplies, and so on. See **mathematical equation.**

statistical F-test A standard statistical test that is applied to the ratio of two estimates of variance to determine whether there is a statistically significant difference between the variances of the distributions from which the estimates are made. See **mean; variance.**

statistical level A specific setting of a factor such as 50°C at 45 rpm.

statistical material selection, reliability of Virtually all classical design equations assume single-valued, real numbers. Such numbers can be multiplied, divided, or otherwise subjected to real-number operations to yield a single-valued, real-number solution. However, statistical materials selection, because it deals with the statistical nature of property values, relies on the algebra of random variables. Property values described by random variables will have a mean value, representing the most typical value, and a standard deviation, which represents the distribution of values around the mean value. This requires treating the mean values and standard deviations of particular property measurements according to a special set of laws for the algebra of random variables. Extensive information can be found in statistical texts. The algebra of random variables shares many elements of structure in common with the algebra of real numbers, such as the associative and cumulative laws, and the uniqueness of sum and product. In combinations of addition and multiplication, the distributive law holds true. See **design safety factor; mean; mean absolute deviation; plastic material selection; reliability; statistical randomization; test data and uniform standards; tubing, microbore; variance.**

statistical material selection, uncertainty in Some engineering random variables carry with them a degree of uncertainty that may be nonstatistical—that is, they cannot be described in terms of mean values and standard deviations. For example, (1) material properties, such as strength, may be influenced by time, corrosion, and fluctuating thermal environments that are not factored into the analysis; (2) frequently a stress analysis may require simplifying assumptions so that as a result, uncertainties are introduced of unknown magnitudes; and (3) uncertainties may arise from processing operations assumed to be constant, such as melt flow. The statistical approach compels the experimenter to specify accurately and completely those factors that influence the properties under examination. Equally important, the technique requires that those factors that cannot be specified accurately are recognized and considered in assessing property values. See **mean and standard deviation.**

statistical mean absolute deviation See **mean absolute deviation.**

statistical measure Statistic and mathematical function of a statistic.

statistical mechanics Systems that have many degrees of freedom and a wide range of possible states. An exact classical or quantum mechanical description of the full system is usually impossible, but a great deal can be understood about the average properties of these systems by using the concepts and methods of statistical mechanics. Plastic systems are naturally adapted to be studied by statistical mechanics and may be used for readily illustrating its general principles.

statistical median The middle value in an array arrangement in sequence. Thus, 1, 5, 9, 13, and 17 results in a median of 9.

statistical method A method of deriving information from a given set of data (analysis) to meet product performance requirements as well as solving problems. Conversely, it minimizes the amount of data needed to derive specific information.
statistical mode A frequent value or could be several in a set such as bimodal or trimodal. See **modal.**
statistical, non- See **statistical material selection, uncertainty in.**
statistical normal curve Although there are as many different statistical universes as there are conditions, they are usually described by the common types called *normal curve* or *Gaussian distribution.* The normal curve or normal universal distribution is a symmetrical, unimodal, bell-shaped distribution with the mean, median, and mode having the same value. A universal curve or distribution is developed from a frequency histogram. Much of the variation in industry and in nature follows this frequency distribution of the normal curve. The normal curve is such a good description of the variations that occur to most quality characteristics in industry that it is the basis for many quality-control techniques. The area under the bell-shaped curve is equal to 1.00 (when using the formula for the normal curve) or 100% and therefore can be easily used for probability calculations. See **brittleness temperature; mean and standard deviation; quality control.**
statistical parameter A characteristic of a population that is constant.
statistical phase/reasoning Descriptive or deductive statistics describe and analyze a subject group. Inductive statistics determine from a limited amount of data (sample) an important conclusion about a much larger amount of data (universe). Since these conclusions or inferences cannot be stated with absolute certainty, the language of probability is often used. See **probability.**
statistical population A group that is infinite in size and contains all those things of interest that have one thing in common.
statistical population parameter A fixed value characterizing a certain aspect of a statistical population. An estimate of the value of the population parameter, derived from a sample, is called a *sample estimate* or *statistic.*
statistical precision The limits that, with a given probability, include the estimated or obtained value. For example, tensile strength of 25,000 psi (172 MPa) and ± 2,000 psi (14 MPa) has a 50% probability.
statistical probability 6-sigma Based on the statistical normal curve evaluation, a statistical probability in manufacturing that, for example, is greater than 99.9% of all manufactured products in a lot of one billion will fall within specification. See **probability.**
statistical process control (SPC) A method by which a production process can be monitored and control plans can be initiated to keep quality standards within acceptable limits. There are basically two possible approaches for real-time SPC. The first, done online, involves the rapid dimensional measurement of a part or a nondimensional bulk parameter such as weight and is the more practical method. In contrast to weight, other dimensional measurements of the precision needed for SPC are generally done offline, the second approach, and result in a response that is too low. Also obtaining the final dimensional stability needed to measure a part may take time. For example, amorphous injection molded plastic parts usually require at least a half hour to stabilize. See **amorphous plastic; computer processing control, statistical; quality control.**
statistical quality control (SQC) A method for measuring product quality and providing a tracking mechanism to reveal any shifts in level of quality. It is a derivative practice based on the results of SPC. Conceptually, SQC can reject parts that do not conform to the approved standard sample. In practice, parts are physically rejected and diverted into reclamation or recycling systems. Alarms are provided at the machine and at the central computer to inform people (workers, management, etc.) of the rejects. SQC is a scientific method of analyzing data and using the analysis to solve practical problems. See **quality control; statistical process control; tubing, microbore.**
statistical quality control monitoring See **extruder-web tension control, slipping and tearing.**
statistical randomization A method of sequencing experiments by using a random number table so that each experiment in the proposed plan has an equal chance of being the first, second, or last experiment. This is an extremely effective technique for minimizing errors. See **error; error, random.**
statistical range The measured spread of data around the control value; the difference between the highest and lowest values of the variables in the sample.
statistical R chart A statistical variation over time.
statistical regression method Statistical procedures dealing with the study of the association or relationship between two or more variables.
statistical value See **A-basis; B-basis; C-basis; typical basis.**
Staudinger, Hermann (1881–1965) In 1920 Hermann Staudinger, a German chemist, put forward a theory about the chemical nature of a whole group of substances that were natural and synthetic. He called them *macromolecules* or the giant molecules. Today we tend to call them *polymers.* It took 15 years to persuade his fellow chemists of the validity of his theory. His theory explained the nature of plastics and also indicated the ways in which they could be made. It provided the foundation for the world of plastics as we know it. In 1953 he received the Nobel Prize.

To clarify the then new chemistry of macromolecules, he spoke of the monomer molecules as the building blocks. When linked together by polymerization these form the structure of the polymer molecule. The size and shape of the building blocks and the way they are arranged in the polymer molecule will affect the structure and properties of the molecules and hence those of the plastics material. Thus the monomer units have the same relationship to the plastic products as building bricks have to a completed building. Similarly the cement in the building has the same function as the bonds that link the monomer molecules into the polymer chain. Buildings and molecules may be large or small, simple or complex. See **chemical bond; molecular-arrangement structure; molecule, macro-; monomer; plastic history; polymerization.**

steady state A characteristic of a condition, such as value, temperature, pressure, and amplitude, exhibiting only negligible change over an arbitrary long period of time.

steam molding See **expandable plastic steam molding.**

steam vulcanization cure See **extruder wire and cable process.**

stearate The metallic salts, such as aluminum, calcium, and zinc, of stearic acid used as lubricants in certain plastics.

steatite An insulating material that is made from talc plus clay. See **talc.**

steel See **iron; metal.**

steel impregnation See **metal impregnation.**

steel modulus versus specific gravity See **modulus versus specific gravity.**

steel, photoetching tool See **photoetching tool.**

steel recycled See **recycling steel with vinyl scrap.**

steel resources, limited In 1938 it was predicted that U.S. iron ore bodies in the Lake Superior district would be exhausted by the early 1970s. It did not occur because, as usual, new technologies were developed. See **oil resources, limited; plastic myth and fact.**

steel rod reinforced See **coating, steel-rod; concrete, reinforced.**

steel rule die See **cutter die.**

steel, stainless See **iron, stainless steel.**

steel, tool See **photoetching tool.**

stencil See **printing, screen.**

stenter frame Usually called *tenter frame.* See **orientation, tenter frame and roll.**

step-growth polymerization See **polymerization, bulk.**

steradian See **geometric steradian.**

stereoblock plastic A plastic with molecules made up of blocks or long sections of identical stereospecific structures interspaced with sections of another type of structure.

stereochemistry See **chemistry, stereo-.**

stereograph plastic A plastic consisting of chains of an atactic polymer grafted to chains of an isotactic polymer. For example, atactic PS plastic can be grafted to isotactic PS under suitable conditions to provide different properties.

stereoisomer See **molecular structure, stereoisomer.**

stereolithography modeling See **prototyping modeling, stereolithography.**

stereoregular, plastic According to IUPAC definition, a material the molecules of which can be described in terms of only one species of stereo-repeating units in a single sequential arrangement. A unit is a configurational unit having a defined configuration at all sites of isomerism in the main chain of a polymer molecule. See **molecular-arrangement structure.**

stereospecific plastic A term used to describe plastics, such as polypropylene, whose arrangement of molecules is in a specific order and closely packed together to give a high degree of crystallinity. See **atactic plastic; crystalline plastic; isotactic plastic.**

steric hindrance A spatial arrangement of the atoms of a molecule that blocks a reaction of the molecules with another molecule.

sterile According to the U.S. Food and Drug Administration, the average production lot is thought of as being sterile by a majority of the recognized experts in sterilization only when the probability of having a nonsterile unit is less than one in a million. See **probability; quality system regulation.**

sterilization The complete destruction of all bacteria and other infectious organisms in a product, such as an industrial, medical, or food product. Where applicable, it is followed by aseptic packaging to prevent contamination, usually by hermetic sealing. Various physical and chemical sterilization techniques are used, each with its own advantages and limitations. These include chlorine dioxide, dry heat, electron-beam (E-beam) radiation, ethylene oxide (EtO), formaldehyde, gamma radiation, gas plasma, glutaraldehyde, hypochlorite, ionization radiation, microwave, peracetac acid, phenol, ozone, quaternary salt, steam, ultraviolet radiation, vapor-phase hydrogen peroxide, and x-ray. See **electron beam; ethylene oxide; packaging, aseptic; sterilization, heat.**

sterilization chemical indicator Biological indicators (BIs) are used to ensure proper sterilization with chemical indicators (CIs) becoming a potential.

sterilization, gas plasma A method of exposing products to be sterilized to reactive chemicals that are generated by a body of ionized gas or plasma. See **ionization.**

sterilization, heat Both steam or dry-heat methods are used extensively in hospitals. Steam sterilization, which is also known as *autoclave,* involves exposure of material to saturated steam at temperatures higher than 100°C (212°F) for a predetermined time. Dry-heat sterilization is carried out in a hot-air oven. Because microorganisms are more resistant to dry heat than wet heat, the temperatures used are higher and the exposure times longer than those used for autoclave sterilization. See **autoclave.**

sterilization quality assurance (SQA) A comprehensive, integrated program that incorporates such interrelated factors as product packaging and process-control validation, sterilant selection and sterilizing process validation, and control of the manufacturing environment. See **ISO-9000 certification; quality assurance; quality system regulation; sterilization radiation, certification worldwide.**

sterilization, radiation Sterilization through radiation—that is, the emission of energy such as light and heat or the transfer of energy through space by electromagnetic waves. See **irradiation; radiation polymerization; radiation-resistant plastic.**

sterilization, radiation, certification worldwide When choosing irradiation to sterilize medical devices, U.S. manufacturers have historically relied on U.S. Food and Drug Administration guidance and generally followed validation methods prepared by the Association for the Advancement of Medical Instrumentation. Even though this approach continues, manufacturers in the worldwide marketplace now must also consider the European Medical Directory. AAMI members have been working with the International Organization for Standardization and the American National Standards Institute (ANSI) to produce voluntary, harmonized guidance for validation and testing methods. The European Union has also enacted mandatory standards for its members to achieve simultaneous compliance with these various standards. See **American Standards for Testing Materials; ISO; orientation and heat-shrinkability; sterilization quality assurance.**

sterilization, vapor-phase hydrogen-peroxide Liquid hydrogen peroxide has long been used as a disinfectant in both health-care facilities and industrial processes. More recently, it has been used as a highly effective sterilant with a broader range of operation than ethylene oxide.

stiffness A measure of the modulus for a material; the relation of load to deformation; the ratio between the applied stress and resulting strain. The term often is used when the relationship of stress-strain does not conform to the definition of Young's modulus. See **modulus and stiffness; modulus of elasticity; stress-strain stiffness; test, Clash-Berg stiffness.**

stiffness, bending The force required to produce a bent configuration under specified conditions.

stiffness in flexure See **flexural, apparent.**

stir-in plastic See **vinyl plastic, stir-in.**

stock **1.** A charge/quantity of plastic. **2.** A compound in the rubber industry, with compound being the preferred term in the plastic industry. Also called *melt* or *plastic.* See **compound.**

stoichiometry The control of tolerances, levels, and amounts in a chemical mix. When exact amounts necessary for reactions are present without excess reactants, the reaction is said to be stoichiometric. See **equilibrium constant; reaction quotient; reactor technology.**

stoke See **viscosity, stoke.**

Stoke's law **1.** In the atomic process, the wavelength of fluorescent radiation, where it is always longer than that of the exciting radiation. See **fluorescent.** **2.** The rate at which a spherical particle will rise or fall when suspended in a liquid medium. It varies as the square of its radius; the density of the particle and the density and viscosity of the liquid are essential factors. This law is used in determining sedimentation of solids.

stone Various stone aggregates (pebbles, powder, etc.) are used as plastic fillers or reinforcements, particularly in thermoset plastics.

storage Keeping (storing) materials, tools, additives, and equipment spare parts. The different products to be stored usually have specific requirements, such as temperature, height of loads, and handling of plastic form (pellets, powder, etc.). See **A-B-C analysis; auxiliary equipment; blockage; cost, demurrage; data-management system; drying; inventory; material handling; warehousing.**

storage and condensation If a plastic is stored in a relatively cold area, then when it is brought into the operating plant, it will often become wet (due to moisture condensation) enough to cause processing problems. Different procedures can be used to eliminate this problem area, such as moving material to an indoor closed storage bin to expose the plastic to room temperature. See **condensation; quality control.**

storage, material All storage and unloading areas should be kept clean and dry to minimize fire hazard. The store room should be separated from the processing shop by fire-resistant doors. Materials should be stored away from direct sunlight and in properly constructed racks, containers, or silos. Usually the use of unheated storage areas with natural ventilation is sufficient. To ensure that the plastic does not stagnate in storage, adopt a strict first-in, first-out (FI-FO) stock-control policy. With stock control, if a faulty batch develops, one can find the rest of that batch. See **barcode; bulk storage; conveying, pneumatic; inventory; laser marking; material blocking; material handling; plastic material; warehousing.**

storage data See **computerized electronic document and retrieval system.**

storage life See **shelf life.**

storage, silo For processors that can make (truck or rail car) bulk purchases, silos with automatic plastic handling systems, though initially costly, will provide economic paybacks; provide environmental benefits; save floor space, particularly when located outside; reduce work hours; and leave no mess on shop floors as with sacks, gaylords, or big bags. See **auxiliary equipment; bulk storage; plastic material.**

storage tank evaporation See **microsphere.**

strain The per unit change, due to force, in the size or shape of a body referred to its original size and shape. Strain is nondimensional but is usually expressed in unit of length per unit of length or percent. It is the natural logarithm of the ratio of gauge length at the moment of observation instead of the original cross-sectional area. It is applicable to tension and compression tests. Strain aging can be induced by cold working the plastic. See **design, Poisson's ratio in; tensile gauge length.**

strain, alternating amplitude Analogous to the alternating amplitude of stress; a sequence of alternating stress amplitude. See **stress, alternating-amplitude.**

strain amplitude The ratio of the maximum deformation, measured from the mean deformation to the free length of the unstrained test specimen. Strain amplitude is measured from zero to peak on one side only.

strain analysis, moire fringe See **test, nondestructive moire fringes analysis.**
strain analysis, photoelastic See **test, nondestructive photoelastic stress-analysis.**
strain and elasticity A plastic where its elasticity permits recovery of its shape and size after being subjected to deformation exhibits a Hookean or ideal elasticity. See **elasticity; modulus of elasticity; viscoelasticity.**
strain, axial The linear strain in a plane that is parallel to the longitudinal axis of the test specimen.
strain, critical The strain at the yield point.
strain design factor See **design, reinforcement.**
strain deviation See **deviation, root-mean-square strain.**
strain, elastic See **test, nondestructive photoelastic stress-analysis.**
strainer A device that forces plastic melt through some type of sieve to remove extraneous and contaminated material. See **screen pack.**
strain evaluation See **test, nondestructive moire fringe-analysis.**
strain extensometer A device for determining elongation of a test specimen as it is strained when conducting tests. See **stress-strain measurement.**
strain extensometer, laser beam Strain is monitored using laser beam technology. See **sensor, laser.**
strain, flexure of fiber The maximum strain in the outer fiber occurring midspan in a reinforced plastic test specimen.
strain, frozen See **stress, residual.**
strain gauge A device that measures strain in a stressed material based on the change in a wire's electrical resistance. See **injection-molding machine tie-bar measurement; sensor, fiber-optic; transducer, magnetostrictive.**
strain hardening An increase in hardness and strength caused by plastic deformation shear strain at temperatures lower than the crystallization range of the plastic. See **deformation, plastic; hardening.**
straining See **stress softening.**
strain, initial The strain that is produced in a specimen by given loading conditions before creep occurs.
strain, linear During testing (tensile, compression, etc.), the change per unit length or percent deformation due to an applied force in an original linear dimension.
strain, logarithm decrement The natural logarithm of the ratio of the amplitude of strain in one cycle to that in the succeeding cycle during a free vibration. See **logarithm.**
strain, macro- The mean strain over any finite gauge length of measurement large in comparison with interatomic distances.
strain, mean See **fatigue stress, mean; mean.**
strain, micro- The microstrain over a gauge length comparable to interatomic distances.
strain, natural See **strain, true.**
strain, nominal The strain at a point that is calculated in the net cross-section by simple elastic theory without taking into account the effect on strain produced by geometric discontinuities such as holes, grooves, or filters.
strain rate It is the rate of change with time. See **Boltzmann superposition principle; thermoforming, superplastic.**
strain ratio The algebraic ratio of two specified strain values in a strain cycle. Two commonly used ratios are that of the strain amplitude and the ratio of the minimum strain to the maximum strain.
strain relaxation The reduction in internal strain over time. See **creep relaxation; relaxation; stress relaxation.**
strain relief A dimensional change brought about by subjecting the material to an elevated temperature.
strain, residual The strain associated with residual stress. See **test, nondestructive residual strain.**
strain set The strain remaining after complete release of the load producing deformation. See **set.**
strain, subpermanent set The strain retained at the end of a finite interval following release of stress.
strain, thermal Linear thermal expansion, sometimes called *thermal strain* (or changes due to the effect of heat). It is not to be considered strain in mechanical testing.
strain, transverse The linear strain in a plane that is perpendicular to the loading axis of a test specimen.
strain, true The natural logarithm of the ratio of gauge length at the moment of observation to the original gauge length for the specimen subjected to an axial force. Also called *natural strain* or *logarithm strain.*
strain, true plastic Inelastic component of true strain.
strain, winding See **extruder-roll winding strain.**
strand See **filament strand.**
strand spliced See **yarn, spliced.**
strapping tape Narrow-width sheeting that is usually oriented to maximize its performance (strength, etc.). It has important uses in packaging where only steel straps were used in the past. Steel, plastic, and other materials have various advantages and disadvantages. For example, when strapping is used where heat could fluctuate, as in railroad boxcars or storage rooms, the steel at high temperature would expand and cause what it contained to become loose. The elastic deformation lets plastic retain their tension with temperature change. See **extruder flat-film tape; orientation; tension tie.**
strategy resource See **World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**
straw See **fiber, straw.**
streak A surface blemish on plastic products, particularly sheet materials, that occurs in a narrow strip or band. See **defect.**
streamlined die See **die shape.**
strength **1.** The stress required to break, rupture, or cause a failure of a substance. **2.** The property of a material

that resists deformation induced by external forces. **3.** The maximum stress that a material can resist without failure for a given type of loading. See **stress, adhesive dry strength; adhesive peel strength; dielectric strength; fatigue strength; flexural strength; fracture strength; impact strength; melt strength; plastic green strength; rupture strength; shear strength; tear strength; tensile green strength; tensile strength; torsional strength; yield strength.**

strength, cross-breaking The ability of a plastic to withstand loads perpendicular to its surface. See **flexural strength.**

strength, Elmendorf See **tear, tear-resistance.**

strengthening plastic mechanism With some exceptions, strengthening of plastics is the work of the polymer chemist. Exceptions include strengthening by a postmolding thermal treatment (such as heat treating steel or even heat treating plastics), additives, and stretch-orienting plastic products or fabricating reinforced plastics. See **design theory and strength of material; directional property; orientation; reinforced plastic; strength of material.**

strength of material The structural engineering analysis of a part that determines its strength properties. See **chemical composition and properties of plastic; design theory and strength of material; orientation; strengthening plastic mechanism.**

strength, pull Bond strength obtained by a perpendicular pull applied to a surface of the layer. See **bond strength.**

strength ratio The hypothetical ratio of the strength of a product to the strength it would have if no weakening defects are present.

strength service factor A factor that is used to reduce a strength value to obtain an engineering design stress. The factor may vary depending on the service condition, the hazard, the length of service desired, and the properties required of the product. This factor is part of a safety factor. See **design safety factor.**

strength, specific The specific strength at the point of initial failure.

strength, ultimate The maximum unit stress a material will withstand when subjected to an applied load in a tension, compression, or shear test.

strength, wet The strength of a material determined immediately after removal from a liquid in which it has been completely immersed under specified conditions of time, temperature, and pressure. See **joining, wet-installation; saturation, wet strength.**

stress The intensity, at a point in a body (product, material, etc.), of the internal forces (or components of force) that act on a given plane through the point causing deformation of the body. It is the internal force per unit area that resists a change in size or shape of a body. Stress is expressed in force per unit area and reported in MPa and psi. As used in tension, compression, or shear, stress is normally calculated on the basis of the original dimensions of the appropriate cross-section of the test specimen. This stress is sometimes called *engineering stress*; it is different from true stress. See **stress, true; test, residual-stress.**

stress, adhesion See **adhesiveness.**

stress, alternating-amplitude A stress that varies between two maximum values that are equal but with opposite signs, according to a law determined in terms of the time. Also called *alternative stress*. See **strain, alternating-amplitude.**

stress amplitude The ratio of the maximum applied force, measured from the mean force to the cross-sectional area of the unstressed test specimen.

stress amplitude, alternating A test parameter of a dynamic fatigue test. One-half the algebraic difference between the maximum and minimum stress in one cycle.

stress analysis moire fringe See **test, nondestructive moire fringe-analysis.**

stress analysis, photoelastic See **test, nondestructive photoelastic stress-analysis.**

stress concentration Sections, such as sharp corners, holes, and notches, in a fabricated part where physical or molded-in forces are high and cause stress concentrations. See **inspection, infrared.**

stress concentration factor The ratio of the maximum stress in the region of a stress concentrator, such as a hole, to the stress in a similarly strained area without a stress concentrator.

stress, cooling During a melting process, such as injection molding, plastic melts are subjected to processing pressure forces. The stresses produced can remain in the plastics during cooling as frozen stresses and could potentially cause the product to be damaged. See **stress relieving; stress, residual.**

stress corrosion An attack on areas under stress in a corrosive environment, where such an environment alone (no stress) would not have caused corrosion to a material. See **corrosion.**

stress crack The appearance of external or internal cracks in the material as a result of stress that is lower than its short-term mechanical strength and is frequently accelerated by the environment to which the plastic is exposed. See **crazing; environmental stress cracking; orientation, accidental; reinforced-plastic microcracking.**

stress-cracking failure The failure of a material by cracking or crazing some time after it has been placed under load. Time-to-failure can range from minutes to many years.

stress-cracking, thermal The crazing and cracking of some thermoplastics from exposure to elevated temperatures. See **crack; crazing.**

stress, cure See **curing stress.**

stress decay See **stress relaxation.**

stress decrease See **stress relaxation.**

stress determination See **test, nondestructive photoelastic stress-analysis.**

stress, elastic-limit The greatest stress which a material is capable of sustaining without any permanent strain remaining on complete release of stress. A material passes its elastic limit when the load is sufficient to initiate nonrecoverable deformation. See **concavity factor; extruder-web stretching and tearing; melt elasticity; modulus of resilience; stress-strain ratio.**

stress equal in all directions See **pressing, isostatic.**

stress, engineering The stress calculated on the basis of the original cross-sectional dimensions of a test specimen. See **stress, true.**

stress evaluation See **test, nondestructive moire fringe-analysis.**

stress, fracture In structural design analysis, the true, normal stress on the minimum cross-sectional area at the start of fracture. See **energy absorption; stress whitening.**

stress, frozen-in An undesirable "frozen-in" or residual stress. See **adhesive, solvent; orientation, accidental; stress, residual.**

stress, hoop The tensile or circumferential stress in a wall of a material of cylindrical form that is subjected to internal or external pressure. See **test, NOL ring.**

stress, inelastic See **deformation, inelastic.**

stress, initial The stress that is produced by strain in a specimen before stress relaxation occurs. Also called *instantaneous stress.*

stress, internal adhesive See **adhesive stress, internal.**

stress, mass fiber See **fiber stress, mass.**

stress, mean See **fatigue stress, mean.**

stress measurement See **pressure-detecting film.**

stress, nominal The stress at a point calculated on the net cross-section without taking into consideration the effect on stress of geometric discontinuities, such as holes, grooves, slots, or fillets.

stress, normal The stress component that is perpendicular to the plane on which the forces act. The *principal normal stress* is the maximum or minimum value of the normal stress at a point in a plane considered with respect to all possible orientations of the considered plane. On such principal planes the shear stresses are zero. There are three principal stresses on three mutually perpendicular planes. The states of stress at a point may be (1) uniaxial (a state of stress in which two of the three principal stresses are zero), (2) biaxial (a state of stress in which only one of the three principal stresses is zero), and (3) triaxial (a state of stress in which none of the principal stresses is zero). There is also a multiaxial condition that refers to either biaxial or triaxial. See **directional property; orientation.**

stress-number of cycle diagram See **fatigue S-N diagram.**

stress observed See **test, microdynamometer.**

stress, offset yield The stress at which the strain exceeds by a specified amount the offset (such as 0.1% of strain) or extension of the initial proportional part of the stress-strain curve. It is force per unit area (kPa, MPa, or PSI). This measurement is useful for materials whose S-S curve in the yield range is of gradual curvature. Also called *engineering yield strength.*

stress-optical See **coefficient of optical stress.**

stress, plane A state of stress in which the normal stress to the plane under consideration is zero. Thus a thin sheet parallel to this plane has stress-free surfaces. If the Z-direction is that of the normal to the plane, then it is a principal direction because the shear stresses are zeros. Also called *biaxial stress.* See **Mohr circle.**

stress, pressure See **pressure, hydrostatic.**

stress, principal (normal) See **stress, normal.**

stress ratio The algebraic ratio of two specified stress values in a stress cycle. Two commonly used stress ratios are (1) the ratio of the stress amplitude to the mass stress and (2) the ratio of minimum stress to the maximum stress.

stress relaxation **1.** The decrease in stress after a given time at constant strain that can cause warpage, dimensional changes, or complete damage to the part. Also called *stress relieving* or *stress decay.* **2.** The time-dependent decrease in stress in a solid material or product as a result of changes in internal or external conditions. See **creep relaxation; electroplating; insert molding; Maxwell model; modulus, stress relaxation; relaxation; viscoelasticity; zero time.**

stress relieving Heating a plastic to a suitable temperature, holding it long enough to reduce residual stresses, and then cooling slow enough to minimize the development of new stresses.

stress, remaining The stress remaining at a given time during a stress-relaxation test.

stress, residual The stress that exists in a body at rest, in equilibrium, and at uniform temperature and is not subjected to external forces. It is often caused by the stresses remaining in a plastic part as a result of thermal or mechanical treatment in fabricating parts. Usually it is not a problem in the finished product. However, with excess stresses, the product could be damaged quickly or after being put in service from a short to long time depending on amount of stress and the environmental conditions around the product. See **birefringence; crazing; insert molding; light index of refraction; polarized light; stress, cooling; stress relieving; test, residual stress; tolerance and warpage.**

stress riser See **stress concentration.**

stress, root-mean-square See **deviation, root-mean-square stress.**

stress, shear See **shear stress.**

stress softening The smaller stress required to strain a material to a certain strain, after a prior cycle of stressing to the same strain followed by removal of the stress. It is primarily observed in filled elastomers or rubbers (known as the *Mullen effect*), where it results from the detachment of some plastic molecules from filler particles in the first cycle

and therefore cannot support the stress on subsequent straining to the same strain level. See **test, burst Mullen.**
stress stimulation See **plastic, smart.**
stress, specific The load divided by the mass per unit length of the test specimen.
stress, static Stress in which the force is constant or slowly increasing with time, such as a test without shock.
stress-strain Stiffness at a given strain. See **design, EI theory; melt elasticity; modulus of elasticity.**
stress-strain curve Simultaneous readings of load and deformation converted to stress and strain, plotted as ordinates and abscissas, respectively. The S-S relationship applies under test conditions of tension, compression, or torsion. The area under this curve provides valuable information regarding the characteristics of a material such as toughness. Also called a *S-S curve* or *stress-strain diagram.* See **concavity factor; cross-linking network characteristic; directional property, abscissas; directional property, ordinate; energy deformation; fatigue S-N diagram; shear stress-strain; strain gauge; tensile stress-strain curve; test, force-extension; torsional stress; toughness; x-y recorder.**
stress-strain force See **test, force-extension.**
stress-strain measurement Testing machines can provide and develop stress-strain curves. Different types of extensometers are used on test specimens to record and plot strain measurements versus the increasing stress loading that result in stress-strain curves. See **strain extensometer; strain gauge.**
stress-strain measurement, brittle lacquer technique See **test, nondestructive stress-strain measurement, brittle lacquer technique.**
stress-strain measurement under the curve See **toughness.**
stress-strain ratio The ratio of stress to strain in a material at a specified stress or strain. When it is below the elastic limit, it is known as the *secant modulus.* See **modulus, secant; stress, elastic-limit.**
stress-strain stiffness The stiffness expressed in psi or MPa at a given strain. See **stiffness.**
stress-strain-time See **creep isometric and isochronous graph; test, short-time-behavior.**
stress-strain versus temperature See **CAMPUS database.**
stress, thermal See **stress, residual.**
stress, true Stress along the axis calculated on the actual cross-section at the time of the observation (failure) instead of the original cross-sectional area. Applicable to tension and compression testing. See **stress, engineering.**
stress, uniaxial A load condition where a material is stressed in only one direction along the axis or centerline of the part.
stress, waved An alternative stress acting together with a permanent stress.
stress whitening The appearance of white regions in a material when it is stressed. Stress whitening or crazing is damage that can occur when a thermoplastic is stretched near its yield point. The surface takes on a whitish appearance in regions that are under high stress. It is usually associated with yielding. For practical purposes, stress whitening is the result of the formation of microcracks or crazes that is a form of damage. Crazes are not true fractures because they contain strings of highly oriented plastic that connect the two flat surfaces of the crack. These fibrils are surrounded by air voids. Because they are filled with highly oriented fibrils, crazes are capable of carrying stress, unlike true fractures. As a result, a heavily crazed part can carry significant stress even though the part may appear fractured. It is important to note that crazes, microcracking, and stress whitening represent irreversible first damage to a material that could ultimately cause failure. This damage usually lowers the impact strength and other properties. In the total design evaluation, the formation of stress cracking or crazing damage should be a criterion for failure based on the stress applied. Also called *crazing.* See **crazing; environmental stress cracking; stress, fracture.**
stress wrinkle A distortion in the face of a bonded laminate that is caused by uneven web tensions, slowness of plastic setting or curing, selective absorption during bonding, or reaction between fillers and/or reinforcements and plastic. See **laminate; reinforcement.**
stretch An increase or elongation in the dimensions of a material. See **forming; orientation; thermoforming.**
stretch blow molding See **blow molding, stretched.**
stretch elastomer See **heat effect, Gough-Joule.**
stretching See **forming; extruder-web stretching and tearing.**
stretch ratio See **forming, stretch and draw ratios for pressure.**
striae See **wave.**
striation **1.** A longitudinal line in a part that is caused by a disturbance in the melt path during fabrication. **2.** The rippling that occurs in an extruded blow-molded parison that may or may not damage the blown part. See **blow-molding extruder parison. 3.** The separation of color that results in the linear effect of color variation due to incomplete mixing or melting of the plastic.
strict liability See **legal matter: product liability law.**
strict reliability See **legal matter: plaintiff; legal matter: product liability law; reliability.**
strip **1.** To remove relatively volatile components within plastics by distillation or evaporation. See **distillation; evaporation; venting. 2.** A transparent or color viewing strip that is incorporated during processing, such as blow molding, extrusion, and injection molding. Similar or dissimilar plastics can be used. See **blow-molding stripping. 3.** To rapidly remove a color from an improperly dyed fiber, fabric, or printing press by a chemical reaction. Commonly used strippers include sodium hydrosulfide, titanous sulfate, and sodium or zinc formaldehyde sulfoxylates.

stripping fork A tool that is usually made of brass or plastic used to remove parts from a die, mold, or screw. etc. Also called a *comb.* See **cleaning.**
stripping metal surface See **coating, fluidized bed metal stripping.**
stroboscope An instrument that is used to determine speeds of rotation or frequency of vibration made in the form of a revolving disk with holes around the edge through which an object is viewed or a rapidly flashing light that illuminates an object intermittently. See **photoelasticity.**
stroke See **clamping stroke maximum.**
structural adhesive A substance that is used for transferring required loads between adherends that are exposed to service environments, such as severe weather conditions for automotive and aircraft structures, ocean dock platforms, and underground equipment. The adhesives are available in forms that include pastes, films, water-base systems, solvent-base systems, and hot melts. Plastics used include epoxies, nylons, polyimides, silicones, acrylics, and polyurethanes. These different forms and types meet different performance requirements.
structural analysis See **design safety factor; design, sandwich-construction; design technology; statistical equivalent loading system.**
structural bond An adhesive bond that joins basic load-bearing parts as an assembly. The load may be either static or dynamic. See **adhesive, structural.**
structural core material See **sandwich core material.**
structural design See **design safety factor.**
structural envelope The cross-sectional area within a body structure, excluding clearances, that may be used to develop a structure.
structural fairing See **structure, secondary.**
structural material See **sheet-molding compound, structural.**
structural modification See **deformation; oxidation degradation, thermal; strengthening plastic mechanism.**
structural reaction injection molding See **reaction-injection molding, structural.**
structural S-glass See **glass.**
structural support See **infrastructure.**
structural-web molding See **molding, structural-web.**
structure A construction of a product made up of dependent or independent components in a definite pattern of organization to meet performance requirements. Geometric and cross-sectional profiles are used, such as spheres, ribs, channels, sandwiches, and many more. Plastic and reinforced-plastic products meet many different performance requirements, and when the price is right, plastics continue to enter new markets and expand present markets. See **plastic and the future.**
structure, micro- A structure that can be seen through a microscope. See **molecular microstructure.**
structure, monocoque See **design monocoque structure.**
structure, primary The mainframe of a product is the primary structure. Examples include aircraft main supports, building main beams, and automobile frames. If the primary structure fails, it would be damaging or catastrophic to the product or people.
structure, secondary A structure that is not critical to the survival of the primary structure. Examples are parts in aircraft and aerospace vehicles that are not critical to safety of operations.
St. Venant's principle See **statistical equivalent loading system.**
S-twist See **twist, direction of yarn.**
styrene A colorless liquid with a strong order. It polymerizes rapidly when exposed to heat, light, or a peroxide catalyst; polymerization may cause it to become explosive. It is toxic by ingestion and inhalation and presents a moderate fire risk. It is used in the plastic production of polystyrene, styrene butadiene rubber, acrylonitrile-butadiene-styrene, styrene-acrylonitrile, and reinforced thermoset polyester plastic. See **catalyst; polymerization; polystyrene plastic; styrol.**
styrene-acrylonitrile plastic (SAN) An amorphous transparent thermoplastic that is prepared by emulsion, suspension, or bulk polymerization. When compared to conventional polystyrene plastics, it provides improved toughness, heat resistance under load, chemical resistance, resistance to stress cracking (crazing), gloss, hardness, and dimensional stability.
styrene-butadiene elastomer (SBR) A high-volume substitute for natural rubber. It does not have NR's overall versatility but meets different performance requirements and is low cost. See **rubber, natural.**
styrene-maleic anhydride plastic (SMA) A copolymer that results in higher heat resistance than the parent polystyrene and acrylonitrile-butadiene-styrene families.
styrene-methylmethacrylate plastic (SMMA) A material that has better weatherability and impact properties than conventional PS plastic. Also called *P(S-MMA).*
styrene monomer emission A workplace hazard because of its toxic or carcinogenic properties. It presents no problems if properly handled. See **safety.**
styrene-oligablock elastomer These thermoplastic elastomer-styrene (TPE-S) are the oldest and most rubberlike of the TPE types. They are relatively low cost.
styrene-paramethylstyrene plastic This general-purpose plastic has commercial success because of its low cost.
styrene plastic or styrenic plastic See **polystyrene plastic.**
styrene-rubber plastic A plastic that is based on styrene polymers and rubbers, styrene being the greatest by mass.
styrenic plastic A large group of plastics that is either whole or partially polymerized from styrene monomer.
Styrofoam Dow Chemical's tradename for its family of expandable polystyrenes.

styrol The name given to styrene by the chemist who first observed the monomer in 1839. The name was changed to styrene by a German researcher in about 1925.
subassembly Two or more parts that form an assembly but having parts that are individually replaceable. See **assembly/joining; joining.**
sublimation The direct passage of a substance from solid to vapor without appearing in the intermediate (liquid) state.
submarine gate See **mold gate.**
subminiaturization The technique where plastics are involved in packaging miniaturized parts using unusual assembly methods for increased volumetric efficiency. See **casting; encapsulation; packaging, electronic.**
substrate Any material that provides a supporting surface for other materials. Also called *web*. See **web.**
sulfonation The introduction into an organic molecule of the sulfuric ester group where the sulfur is linked through an oxygen atom to the parent molecule. This chemical reaction changes surface properties of plastics. See **barrier via chemical modification; fluorination; gasoline tanks; surface CASING.**
sulfone plastic This family of engineering plastics includes polysulfone, polyarylsulfone, polyethersulfone, polyphenylsulfone, polyphenylethersulfone, and polyarylether sulfone. They are amorphous engineering thermoplastics whose main features are very good thermal stability, heat and steam resistance, chemical resistance, stiffness, and electrical properties. See **amorphous plastic.**
sulfuric acid (H_2SO_4) A dense, highly corrosive liquid that is miscible with water and is produced by burning either iron pyrites or brimstone, by the contact or chamber process.
supercritical water oxidation See **waste, pressure cooking.**
supply chain The series of organizations that produce and refine raw materials and process the resulting compounds into products or components of products. A typical plastics supply chain starts with an oil company, then extends to refiners and chemical plants, a plastic compounder, and a fabricator. At the end of the chain are the packaging and distribution channels that lead to a customer and finally the retail operation that presents and sells the merchandise or product. It is a synergistic chain where the system depends either directly or indirectly on all the parts to function. Such systems exist in certain efficient, productive, and advanced worldwide production organizations. See **fabricating; plastic products, raw material to.**
surface The exterior of a product; a plane or curved two-dimensional surface layer.
surface appearance The surface which will be seen in use has to meet a specified standard. See **calendering finish; luster.**
surface, asperity Microscopic surface roughness.
surface CASING A term coined by AT&T Bell Laboratories (now Lucent Technology) as an abbreviation for the process of "cross-linking by activated species of inert gases." It was developed to impart printability and adhesive receptivity to plastics such as fluoroplastics and polyethylene plastics. In this process the products are exposed to a flow of activated inert gases in a glow tube that forms a shell of highly cross-linked molecules on the product's surfaces. This chemically converted surface provides the cohesive strength for printing and adhesive bonding. See **barrier via chemical modification; cross-linking; fluorination; sulphonation.**
surface, class A The highest-quality surface that is technically achievable on exteriors, auto body panels, etc.
surface coating A substance that is applied to materials of all types to protect or decorate surfaces. See **coating; decorating.**
surface, concave See **shape, concave.**
surface conductivity See **electrical-surface conductance.**
surface etching See **chemical etching; photoetching tool.**
surface faying The surfaces of materials that are in contact with each other and joined or about to be joined. See **joining.**
surface film See **bloom.**
surface finish Some manufactured plastic parts require a finishing operation after fabrication. See **alligator-grained surface; ashing; buffing; calcium silicate; decorating; decorating pretreatment; defect; finish; finish, blast; finishing, ashing and lapping; gel, micro-; lacquer; material tumbling; operation, secondary; plastic, low-profile; plating; polishing, solvent; product, semifinished; sanding; spline; surface treatment; waviness.** Tooling surfaces, such as mold cavities and die openings, require certain surface finishes. Sometimes it is difficult to identify the finish required other than by stating dull, vapor-honed satin, shiny, etc. The SPI (originally SPI/SPE) Mold Standard Finish (with six different finish surfaces) and ANSI Standard B46.1 Surface Texture (extremely accurate surface measurements) have been replaced by SPI's worldwide Mold Finish Standard. It has four distinct categories: designation A is the highest polish, having a diamond finish; B is a paper category; C is a stone finish; and D is a blast finish. Each category has three classifications, with 1 being the best and 3 the lowest classification. This standard lists the final step in the mold benching, polishing operation only. The mold surface must be properly prepared by removing defects such as machining markings and other marks. See **finish; mold-cavity surface; molded-material surface measurement; photoetching tool; polish; screw strip, polish plating.**
surface glass coating See **barrier, glass-coating.**
surface imperfection See **defect.**
surface measurement See **molded-material surface measurement.**
surface modification, ion beam See **hydrophilic surface; ion-beam surface modification.**

surface mounted technology See **printed circuit board.**
surface oxidation See **transcrystalline growth.**
surface preparation Various methods are used to treat plastic surfaces for printing, protective coatings, adhesive bonding, and permeation. See **flame treatment; sodium treatment; transcrystalline growth.**
surface pumicing A finishing method for molded parts that consists of rubbing off traces of tool marks and surface irregularities by means of wet pumice stones. See **pumice.**
surface resistivity See **electrical-surface resistivity.**
surface skin The smooth or tailored surface of the plastic that are formed during processing by contacting a tool (die, mold, etc.).
surface, specific The surface area per unit volume or per unit weight.
surface tack The stickiness of a surface of a material, such as wet paint, when touched.
surface tension The cohesive force at a liquid surface that is measured as a force-per-unit length along the surface of the work that must be done to extend the area of a surface by a unit area, such as a square centimeter. Also called *free surface energy*. See **detergent; polyphosphazene plastic; surfactant.**
surface tension, critical The value of surface tension of a liquid below which the liquid will spread on a solid.
surface treatment The method of treating (chemical, flame, electrical, additive, etc.) a part (film, container, etc.) to alter its surface and render it receptive to inks, paints, and adhesives. Various methods are used to render inert plastics (such as polyolefins) more receptive to inks, adhesives, or various decorations. See **abraid; adhesive surface sodium treatment; barrier; chemical etching; chemical milling; chromic acid etching; cleaning; cleaning, abrasion; cleaning, solvents; decorating preparation problem; electrical corona discharge treatment; electronic treatment; film decorating; flame treating; fluorination; fluorine; ion-beam surface modification; machining; photoetching tool; plasma arc treatment; printing ink; sand blast; satinizing; sulfonation; tooling coat; transcrystalline growth.**
surfacing mat See **sheet overlay.**
surfactant A compound that affects interfacial tensions between two liquids. It usually reduces surface tension. See **alkylate sulfonate, linear; detergent; foamed polyurethane; silicone; surface tension.**
surging See **extruder melt-flow oscillation; extruder pressure-head safety; extruder surging; screw transition zone, conical and involute.**
suspension A liquid medium containing a more or less uniform dispersion of fine particles. When the particles are so small that they pass through ordinary filters and do not settle out when left standing, the suspension is known as a *colloidal suspension* or *colloid*. See **aerosol; colloidal; dispersing agent; lyophilic.**
suture See **medical suture.**
swaging An assembly method that is used to form a ring or ridge of thermoplastic on one of the matting parts to capture or assemble the other part. The method can use hot plates, flame, and ultrasonic energy. See **peening.**
sweating The exudation of small drops of liquid, usually a plasticizer or softener additive, on the surface of the plastic part. In certain circumstances, sweating acts as a parting agent. See **additive, slip; antiblocking agent; mold sweating.**
swell **1.** The increase in volume of a material that is immersed in a liquid or exposed to a vapor. See **absorption; gel, zero-. 2.** The usual action when melt exits a die. See **design, basics-of-flow die.**
swell degradation See **degradation, swelling, extraction, and random.**
symbols and signs Many different signs and symbols represent various characteristics that are referred to within and outside the plastic industry. Examples follow:

MATHEMATICAL SYMBOLS AND ABBREVIATIONS

+	plus (addition)	a', a''	a prime, a second
−	minus (subtraction)	a_1, a_2	a sub one, a sub two
±	plus or minus		
×	times, by (multiplication)	( ), [ ], { }	parentheses, brackets, braces
÷, /	divided by (division)		
:	is to (ratio)	∠, ⊥	angle, perpendicular to
::	equals, as, so is	a^2, a^3	a square, a cube
∴	therefore	a^{-1}, a^{-2}	$1/a$, $1/a^2$
=	equals		
∼ ≈	approximately equals	$\sin^{-1}a$	the angle whose sine is
>	greater than	π	pi = 3.141593+
<	less than	μ	microns = .001 millimeter
≧	greater than or equals	mμ	micromillimeter = .000001
≦	less than or equals	Σ	summation of
≠	not equal to	ϵ, e	base of hyperbolic, natural or Napierian logs = 2.71828+
∝	varies as	Δ	difference
∞	infinity	g	acceleration due to gravity (32.16 feet per second)

∥	parallel to		
√	square root	E	coefficient of elasticity
□	square	v	velocity
○	circle	f	coefficient of friction
°	degrees (arc or thermometer)	P	pressure of load
′	minutes or feet	HP	horsepower
″	seconds or inches	RPM	revolutions per minute

GREEK ALPHABET

Α, α	alpha	Η, η	eta	Ν, ν	nu	Τ, τ	tau
Β, β	beta	Ω, θ	theta	Ξ, ξ	xi	Υ, υ	upsilon
Γ, γ	gamma	Ι, ι	iota	Ο, ο	omicron	Φ, φ	phi
Δ, δ	delta	Κ, κ	kappa	Π, π	pi	Χ, χ	chi
Ε, ϵ	epsilon	Λ, λ	lambda	Ρ, ρ	rho	Ψ, ψ	psi
Ζ, ζ	zeta	Μ, μ	mu	Σ, σ	sigma	Ω, ω	omega

symmetric Having corresponding points whose connecting lines are bisected by a given point or perpendicularly bisected by a given line or plane. The opposite of *asymmetric.* See **geometry.**

synchronization See **control drive, optimized.**

syndiotactic Having the asymmetric carbon atoms of successive monomer units in opposite steric configurations. See **polystyrene plastic, syndiotactic.**

syndiotactic stereoisomerism See **chemistry, stereo-; molecule, syndiotactic stereoisomerism.**

syneresis See **gel, syneresis.**

synergism An arrangement or mixture of substances in which the total resulting performance is greater than the sum of the effects taken independently such as with alloying/blending. See **alloy/blend; compound; hybrid; interpenetrating network; reactor, breeder.**

synergist A substance that causes synergism.

syntactic foam See **reinforced plastic, syntactic cellular plastic.**

synthesis See **chemical synthesis.**

synthetic A chemical compound that is made from elements or simple compounds. It is applied particularly to substances that duplicate other substances occurring in nature. See **chemical synthesis; natural; organic; organic, in-; plastic; polysaccharide plastic.**

synthetic, natural A synthesized compound that is relatively identical with natural substances, such as synthetic natural gas and synthetic natural rubber. See **plastic, natural; plastic, synthetic.**

syrup A liquid solution of synthetic plastics.

system All of the equipment, such as in processing line, that is needed to produce a product.

T

Taber abrasion test See **abrasion; testing.**
table-tennis ball See **cellulose nitrate plastic.**
tablet material See **concentrate; pellet; preform.**
tack Stickiness of an adhesive, uncured plastic, or reinforced plastic prepreg. See **adhesive tackifier.**
tack control See **prepreg tack control.**
tack-free time The time between two stages of preparing (mixing and dispensing, coating, etc.), at which time the surface of the substance can be touched without sticking.
tackifier A substance that is added to a plastic or elastomer to improve or provide tack. See **adhesive tackifier.**
tackiness The pull resistance exerted by a material adhering completely to two separate surfaces; the slight stickiness of the surface of a coating that is apparent when it is pressed by a finger and is related to a characteristic of cure.
tack range See **adhesive tack range.**
tack weld See **welding, tack.**
tailor-made See **designing with plastic tailor-made models.**
tailing **1.** The impurities that remain after extraction of useful materials from ore. See **ore. 2.** Any residue from a mechanical refining or separation process. See **residue.**
tailor-made plastic See **designing with plastic tailor-made models.**
take-off The mechanism for drawing calendered, coated, or extruded material away from the output of the machines. The most common forms are a pair of endless caterpillar belts or rolls with resilient grips conforming to the cross-section's shape being drawn (flat, circular, etc.), driven at a speed synchronized with the basic machine output rate. See **cutter; extruder take-off winder; roll.**
talc A natural hydrous magnesium silicate. See **filler versus unfilled compound; steatite; vermiculite.**
tall Tall oil. The term is derived from the Swedish word for pine and is not the same as pine oil. See **oil.**
tamper-proof cap See **medical seal and closure; mold, collapsible-core.**
tangent modulus of elasticity See **modulus, tangent.**
tank Various sizes and shapes are used to fabricate tanks from thermoplastics and reinforced plastics and to meet different performance requirements. Some can hold highly corrosive chemicals or abrasive materials; others can hold water or milk. Processes that are used include injection molding, blow molding, rotational molding, thermoforming, and filament winding. See **rail car contamination; reinforced plastic; thermoplastic.**
tanker truck, reinforced-plastic RP road tankers can optimize the transport of hazardous chemicals. U.S. Department of Transportation approvals have been obtained for these different applications. They are 2,000 lb (900 kg) lighter than steel, carry up to 12wt% larger payloads, reduce overall transportation costs, and have thermal conductivity 30 to 50 times less than steel. Operational efficiency is maximized by the ability to clean the tanker interior easily and quickly. See **rail car contamination; truck and plastic.**
tank, jacketed Double wall tank that can provide insulation to its contents or through which a heat transfer medium is passed allowing the tank to act as a heat exchanger.
tank, liquid oxygen compatibility See **polyarylene ether phosphine oxide plastic.**
tape See **extruder flat-film tape.**
tape, lap wrap Tape wrapped around an object or mandrel in an overlapping pattern.
tape placement wrapped molding See **molding, lagging.**
taper, back See **mold undercut.**
tapping Cutting threads in the wall of a circular hole.
tape strapping See **strapping tape; tension tie.**
tare The weight of a container (railroad car, etc.) that is deducted in determining the net weight of the material in the container. See **weight.**
tariff See **legal matter: tariff.**
taste See **test, organoleptic.**
tax credit, equipment See **capital equipment investment tax credit.**
tear, Elmendorf test See **test, tear-resistance.**
tear failure A tensile failure that is characterized by fracture initiating at one edge of the specimen and progressing across the specimen at a rate slow enough to produce an anomalous load-deformation. See **burst strength; extruder-web stretching and tearing; extruder web tension control, slipping and tearing; failure; punching device; reinforced plastic tear ply; test, impact; test, tear-resistance.**
tear resistance, initial The force that is required to initiate tearing of a flexible plastic film or thin sheeting at very low rates of loading, measured at maximum stress usually found at the onset of tearing.
tear strength The maximum force that is required to tear a specimen; the force acting substantially parallel to the major axis of the specimen.
technical development See **research and development; revolutionary versus evolutionary developments.**
technical conference See **shows and conferences.**
technical cost modeling (TCM) A method for analyzing the economics of alternative manufacturing processes without the prohibitive economic burden of

trial-and-error innovation and process utilization. The adoption of any new technology for producing manufactured products is characterized by a wide range of processes, materials, and economic consequences. Although considerable talent can be brought to bear on the processing and engineering aspects, economic questions remain. Cost problems are particularly acute when the technology that will be employed is not fully understood, as much of cost analysis is based on historical data, past experience, and individual accounting practices. Historically, technologies have been introduced on the shop floor incrementally, with their economic sequences measured on the shop floor incrementally and their economic consequences measured directly. Although incorporating technical changes in the plant to test their viability may have been appropriate in the past, it is usually economically not feasible to explore today's wide range of alternatives in this fashion.

TCM is an extension of conventional process modeling, that emphasizes capturing the cost implications of process variables and economic parameters. By coordinating cost estimates with processing knowledge, critical assumptions (processing rate, energy used, plastic consumed, melt behavior, etc.) can be made to interact in a consistent, logical, and accurate framework of economic analysis, producing cost estimates under a wide range of conditions. For example, TCM can be used to determine the plastic process that is best for production without expensive expenditure of capital and time. TCM can be used to establish direct comparisons between processes, to determine the ultimate performance of a particular process, and to identify the limiting process steps or parameters. It uses an approach to cost estimating in which each of the elements that contribute to total cost is estimated individually. These individual estimates are derived from basic principles and the manufacturing process. TCM reduces the complex problem of cost analysis to a series of simpler estimating problems, and rather than using intuition, it solves them by bringing to bear processing expertise. See **cost.**

technical service Frequently the component that allows a supplier to retain an advantage over a competitor. See **serviceability.**

technical writing Concise and accurate scientific writing is needed in the literature of science and technology and in the proposals, reports, manuals, letters, memos, and other documents produced in the field. Accurate definitions are essential. See **chemistry; computer database; fabricating.**

technology The practice and description of any or all the applied sciences that have commercial value. They provide the basic knowledge for newly emerging plastic products. See **art and science; chemistry; computers; design, innovative; design technology; packaging; plastic and the future; profit and technology; research and development; revolutionary versus evolutionary developments; telecommunication; thermodynamics.**

technology assessment An evaluation of the impact of technology or intervention on a broad array of costs and consequences, including some that may not be quantifiable. The purpose is to identify hidden costs and outcomes that, if known, might change resource allocation or purchasing decisions. See **computer monitoring information; cost analysis; purchase order; research and development.**

Tedlar DuPont's tradename for its family of biaxial oriented polyvinyl fluoride plastics.

Teflon DuPont's tradename for its family of polytetrafluoroethylene plastics.

telcothene plastic In 1937 polyethylene was developed and produced by ICI-England and was quickly identified as the best electrical insulation known. To make it extrudable, it was blended with polyisobutylene plastic and called *telcothene*. Later it was identified as being in the polyethylene family of plastics. See **polyethylene plastic.**

telecommunication Data communication; the transmission of information from one point to another point or from one piece of equipment to another piece of equipment.

telescoping Transverse slipping of successive winds of a roll of material so that the edge is conical rather than flat. See **roll.**

telomere See **molecule, telomere.**

temper To reheat after hardening to some temperature below the critical temperature, followed by air cooling to obtain desired mechanical and other properties by relieving hardened or frozen stresses. See **annealing; hardening, case; stress, residual.**

temperature The thermal state of matter as measured by a specific scale. It is a measure of the intensity of the molecular energy in a substance. The higher temperatures have more molecular movement. The temperature at which molecular movement ceases completely is absolute zero; it has been reached theoretically but not yet in actuality. See **adiabatic flame temperature; antioxidant agent; Celsius; Centigrade; Fahrenheit; Kelvin; measurement; Rankin scale; Reaumur; relative humidity.**

temperature, absolute zero On the Celsius scale it equals −273.16°C (−459.679°F), and with Kelvin it equals zero. The concept of absolute zero stems from thermodynamic postulations. See **boiling point, absolute; temperature, homologous.**

temperature aging See **antioxidant agent.**

temperature, ambient Usually synonymous with *room temperature*. It denotes the surrounding environmental conditions, such as pressure and temperature.

temperature and crystallinity See **glass transition temperature and crystalline melting point.**

temperature and deflection See **deflection temperature under load versus crystallinity.**

temperature and heat transfer See **thermodynamic properties.**

temperature and load See **designing with the pseudoelastic method; load.**

temperature and moisture absorption change See **hygrothermal effect.**

temperature and molecular bonding force The effect of temperature on the bonding forces in a *thermoplastic* (softened by heat) involves two types of bonding forces. The bonds between adjacent chains are very weak and are weakened further by rising temperature. These are sometimes called *secondary bonding forces*. The other type of bond is between monomer units in the polymer chain. These valency bonds are strong and relatively resistant to rising temperatures. When the temperature of a plastic containing identical small molecules is raised high enough to destroy the secondary bonding forces, then the material will melt at one particular temperature. When the molecules in the plastic are of varying sizes and are so tangled together, then instead of one sharp melting point to an easy flowing melt, they soften over a much wider range of temperatures to form a melt that flows with much more difficulty. If the molecules have few branches that increase the distance between the main chains, then the parallel lengths of the chains can form crystalline regions. Since they then pack closely together, the density is higher. Many branched molecules cannot be close together so there will be less crystallinity and the density will be lower. Thus, amorphous plastics do not have a sharp melting point, and crystalline plastics do have a sharp melting point. See **amorphous plastic; crystalline plastic; melt temperature; molecular bonding; Staudinger, Hermann; Valence.** With *thermoset* plastics, where the molecules in the polymer are cross-linked by many valency bonds, then a three-dimensional network will be formed that will not be affected by heat until the temperature is high enough to break up the molecules. Such materials will also be rigid and basically insoluble. See **thermoset plastic.**

temperature and pressure, standard (STP) 0°C at 1 atm.

temperature and pressure uniformity See **thermoforming, pneumatic control.**

temperature and toughness See **molecular weight, toughness, and temperature.**

temperature and volume or pressure change See **isothermal.**

temperature, Avogadro's law See **Avogadro's law.**

temperature conditioning The usual is 23°C + 2°C (73°F + 3.6°F) and 50% + 5% relative humidity. See **laboratory accreditation.**

temperature conductivity, super- The phenomenon in which certain materials at temperatures usually near absolute zero (0°K) lose both electrical resistance and magnetic permeability; they have infinite electrical conductivity. See **plastic, magnetic.**

temperature controller A checklist for eliminating controller problems includes heater element burnout, location and depth of sensor as related to response time, type of on or off control action (such as proportional controller), set point control, and proper basic electrical component selection. Proper depth of the sensor in a barrel is necessary to obtain the best reading for the melt; the deeper the better. Where water is involved, as in mold-cooling controllers, the most common problem (due to expansion and contraction not properly allowed for) is water leaks. With their external pressure-relief valves, they ensure discharge outside the cabinet. With inside discharge, severe damage can occur to mechanical and electrical components. See **chiller; control, fuzzy-logic; coolant; injection-molding melt temperature; maintenance; mold cooling; mold heating; temperature proportional-integral-derivative; temperature shallow well.**

temperature controller, heating overshoot circuit A device that is used in temperature controllers to inhibit temperature overshooting on warm-up.

temperature controller rate term A feature that is added to temperature controllers to anticipate and greatly speed response to changing conditions.

temperature conversion See **Appendix B, Conversion Tables.**

temperature cooling rate See **mold cooling rate.**

temperature, critical The temperature above which a gas will not liquefy.

temperature, damping effect See **damping gamma loss peak.**

temperature, deflection under load See **deflection temperature under load versus crystallinity; testing.**

temperature differential by infrared See **test, nondestructive temperature differential by infrared.**

temperature, dry-bulb The temperature of air as indicated by an accurate instrument corrected for radiation.

temperature, ductile-to-brittle transition See **molecular weight, toughness, and temperature.**

temperature, electrical resistance detector (RTD) A temperature sensor that is made from a material such as high-purity platinum wire. Resistance of the wire changes rapidly with temperatures. These sensors are about 60 times more sensitive than thermocouples. See **temperature sensor.**

temperature flexibility, plastic Flexible (elastomer) plastics at room temperature become less flexible as they are cooled and finally become brittle at some temperature. This property is often measured by torsional test over a temperature range. See **test, torsional; torsional strength.**

temperature, freeze The temperature at which material is rigid enough to be parted or ejected from a device (mold, continuously casting moving belt, etc.).

temperature, heat distortion See **deflection temperature under load; testing.**

temperature, homologous The ratio of the absolute temperature of a material to its absolute melting temperature, usually measured in Celsius. See **melt temperature, absolute; temperature, absolute zero.**

temperature index See **fire retardance.**

temperature, liquid See **glass filament liquid temperature.**

temperature, low See **chemistry, cryo-; cryogenics; ethylene glycol.**

temperature, Martins See **test, Martins temperature.**

temperature measurement Temperatures can be measured with a thermocouple (T/C) or resistance temperature detector (RTD). T/Cs tend to have a shorter response time, while RTDs have less drift and are easier to calibrate. Traditionally, proportional-integrated derivative controls have been used for heating and on-off control for cooling. More recently, fuzzy logic control (FLC) has been used, which, because of the lack of overshoot on startup, results in achieving the setpoint more rapidly. Another unique advantage of FLC is its multivariable control, where more than one measured input variable can affect the desired output result. With PID one measured variable affects a single output variable. Two or more PIDs may be used in a cascade fashion, but with more variables they are not practical to use. See **dilatometer; pyrometer; temperature sensor; thermocouple; thermometer.**

temperature, melt See **melting temperature.**

temperature method 30/30 See **melt-temperature effectiveness.**

temperature properties of plastics Most plastics can take greater heat than humans or buildings can take. Some cannot take boiling water, others operate at 150°C (300°F), and a few up to 540°C (1,000°F). Then there are plastics that reach 1,370°C (2,500°F) with exposures in fractions of a second. Performance is influenced by short- to long-time static and dynamic mechanical requirements. See **ablative plastic; insulation resistance; polymorphism; pyrone plastic.**

temperature proportional-integral-derivative control algorithm Pinpoint temperature accuracy is essential to be successful in many fabricating processes. To achieve it, microprocessor-based temperature controllers can use a proportional-integrated-derivative control algorithm that is acknowledged to be accurate. The unit will instantly identify varying thermal behavior and adjust its PID values accordingly. See **accuracy; algorithm; control drive, optimized; control, fuzzy logic; motion-control system; process control; repeatability; temperature; temperature controller.**

temperature protection See **coating, intumescent.**

temperature rate versus chemical reaction See **chemical reaction versus temperature rate.**

temperature recalescence The increase in temperature that occurs after cooling because the rate of liberation of heat during transformation of a material exceeds the rate of dissipation of heat.

temperature resistance See **chemical and physical characteristics.**

temperature, room (RT) A temperature in the range of 20 to 30°C (68 to 86°F) or as specified with an atmosphere of unspecified relative humidity. See **conditioning; service condition; temperature conditioning.**

temperature, room cure See **adhesive, room-temperature cure.**

temperature, self-ignition See **combustion, autoignition point.**

temperature sensitivity It is generally recognized that increasing the temperature of plastics increases their atomic vibration and molecular mobility, resulting in reduced melt viscosity. Thus, for example, during plastication when a plastic melt is too viscous, the first reaction could be to increase the temperature of the melt. The effect of molecular-weight distribution on this relationship becomes complex. With PEs broadening the MWD decreases the sensitivity of melt viscosity to temperatures, whereas with PSs broadening the MWD increases temperature sensitivity. Methods of expressing molecular averages and distributions, and the combined effects of branching, may be responsible for the discrepancy. See **melt-temperature effectiveness; molecular-weight distribution; polymer, branched.**

temperature sensor A device that is used for temperatures in the ranges experienced in plastic processing equipment. The thermocouple is the most common. The resistant temperature detector provides stability; its variation in temperature is both repeatable and predictable. The thermister is also used. See **sensor; temperature, electrical resistance detector; temperature measurement; thermister; thermocouple; thermometer; zero power resistance.**

temperature set The temperature at which a plastic material (elastomer, adhesive, etc.) produces a product or assembly that is subjected to set (solidify or cure) the material. See **cure.**

temperature shallow well The location of a temperature sensor that is more responsive to changes in ambient rather than melt temperature in a plasticator. It is usually coordinated with temperature measurements in a deep well sensor located near the melt. See **temperature controller.**

temperature shrinkage of plastic See **coefficient of linear thermal expansion.**

temperature, softening range The temperature at which a plastic is sufficiently soft to be distorted easily. Various tests exist, and the temperatures arrived at may vary according to the particular test method. Softening range is sometimes erroneously referred to as the *softening point*. See **softening point; thermomechanical analysis.**

temperature solidification point An empirical constant that is the temperature at which the liquid phase of a substance is in approximate equilibrium with a relatively small portion of the solid phase.

temperature stability The percent change in tensile strength or in percent elongation as measured at a specified temperature and compared to values obtained at the standard conditions of testing.

temperature-time dependent See **designing with the pseudoelastic method.**

temperature, time, pressure cycle See **cycle; process control.**

temperature timing and sequencing Most processes operate more efficiently when functions must occur in a desired time sequence or at prescribed intervals of time. In the past, mechanical timers and logic relays were used. Now electronic logic and timing devices predominate. These programmable logic control devices provide operations with sophisticated and controllable functions.

temperature transition The temperature at which the properties of a material change. Depending on the material, the transition change may or may not be reversible. Also called *ductile-to-brittle transition temperature*. See **mold-cavity melt-flow analysis.**

temperature versus reaction rate See **Arrhenius equation.**

temperature versus time See **exotherm.**

temperature, wet-bulb The temperature that is reached by a wet surface when exposed to air. This temperature together with dry-bulb temperature can be used to determine relative humidity. Measurement is by a psychrometer instrument where an ordinary mercury thermometer has its bulb covered with a wet cloth. When the cloth is exposed to air, the water evaporates and a temperature is indicated.

tempered Reheated to some temperature below the critical heat treating range and subsequently cooled to change properties, such as toughness or brittleness.

tempering See **annealing; hardening, case.**

template A pattern that is used as a guide for cutting material to required shapes for fabricating or assembly.

tenacity See **yarn tenacity.**

tensile analysis A test that is used to characterize the mechanical properties of materials (plastic, metal, wood, etc.). Important information is obtained, such as the material's elastic properties, yield, strength, and toughness based on the stress-strain data obtained. See **stress-strain curve.**

tensile area reduction See **test area reduction.**

tensile bar See **tensile test specimen.**

tensile elastic limit See **stress, elastic-limit.**

tensile elongation, maximum The maximum elongation at the time of failure. Also called *ultimate elongation* or *break elongation*.

tensile elongation, percent The extension of a uniform section of a specimen expressed as percent of the original length.

tensile elongation, ultimate The elongation at the time of rupture.

tensile elongation unit In a tensile test, the ratio of the elongation to the original length of the specimen—that is, the change in length per unit of original length. See **elongation.**

tensile extensometer See **strain extensometer.**

tensile gauge length The length over which deformation is measured for different test specimens. Electronic sensors are used to measure the elongation of tensile test specimens. The deformation over the gauge length determines strain. See **sensor.**

tensile green strength The tensile strength of a raw material, such as unvulcanized rubber or elastomer material. A high green strength is desirable in those processing operations in which the integrity of a shape piece of the material needs to be maintained. While cure is not complete, it allows removal from the mold and handling without tearing or permanently distorting the material. See **plastic green strength; rubber processing; vulcanization.**

tensile heat distortion temperature See **deflection temperature under load; testing.**

tensile hysteresis A retardation of the strain when a material is subjected to a force or load. See **hysteresis loop.**

tensile set The extension that remains after a specimen has been stretched and allowed to retract in a specific manner expressed as a percentage of the original length.

tensile strain recovery The percent of recoverable extension of the total extension that occurs in a material. It includes both immediate recovery and delayed recovery.

tensile strain rupture The elongation that is necessary to cause rupture of the test specimen; the tensile strain at the moment of rupture. See **rupture.**

tensile strength The maximum tensile stress that a specimen can sustain in a test carried to failure. The maximum stress can be measured at or after the failure or reached before the failure. Behavior of failure relates to the materials viscoelastic behavior. Also called *maximum* or *ultimate tensile strength* or *tensile strength at break*. See **cross-linking network characteristic; fatigue strength versus tensile strength; fracture strength; neck-in; plastics, theoretical versus actual values of; strength; stress-strain curve; tensile green strength; test, NOL ring; yield strength.**

tensile stress The force that is related to the original cross-section of the specimen prior to its usual neck-down reduction; however, when the neck-down area is used, technically the actual stress is obtained. See **rheometer, dynamic; stress; yield point.**

tensile stress, actual The force that is related to the smallest cross-section of the test specimen at any time of the test.

tensile stress at a given elongation The stress that is required to stretch the uniform cross-section of a test specimen to a given elongation.

tensile stress necking The localized reduction in cross-section of the test specimen that occurs during its elongation when the loading is applied. See **neck-in.**

tensile stress-strain curve The area under the stress-strain curve is proportional to the energy required to break the plastic; the larger the area, the more energy required. Thus, it is sometimes called the *toughness of the plastic*. However, certain plastics, particularly reinforced plastics, are exceptionally tough, hard, and strong even though their area is extremely small. See **mean and standard deviation; stress-strain curve; toughness.**

tensile test See **test, short-time-behavior; tensile analysis; tensile testing machine.**

tensile testing machine An apparatus that transmits the force to apply a load on the test specimen and simultaneously record the specimen's stretch (strain). A stress-strain curve is provided. They can be programmed to be extremely useful in quality control. See **testing.**

tensile testing-machine test rate The speed at which its cross-head moves. An increase in strain rate typically results in an increasing yield point and strength. Test methods specify speed of testing for the different materials (soft to rigid) to be tested since test results can be affected by the time-dependent factor.

tensile test specimen A properly prepared molded or machined test specimen of specific dimensions that is used to determine the tensile properties. Various shapes and sizes are used to meet performance requirements. Also called a *bar.*

tensile thermal inversion The decrease in tensile force with increase in temperature that is necessary to maintain a constant length of a plastic such as an elastomer. It occurs only at low elongation (less than 10%); at higher elongation thermal-elasticity occurs. It is caused by the thermal expansion of the elastomer that increases the length in the unstrained state and thereby reduces the effective elongation.

tensile viscoelasticity Plastics respond to stress with elastic strain. In these materials, strain increases with longer time and higher temperatures. See **viscoelasticity.**

tensile volumetric change See **tensile stress necking.**

tension A uniaxial force that tends to cause the extension of a body or the balancing force within that body resisting the extension.

tension control See **extruder-roll tension control; extruder-web tension control.**

tension fatigue A fracture through a crack growth of a component or test specimen that is subjected to repeated tensile deformation. See **fatigue.**

tension impact test A method for determining the energy that is required to fracture a specimen under shock tensile loading. See **test, impact.**

tension, interfacial The contractile force of an interface between two phases. See **interface.**

tension member Any component that carries horizontal tension loads.

tension parallel The imposition of a tensile stress that acts in a direction parallel to the longitudinal or fiber direction of a material such as film, sheet, reinforced plastic, or wood. See **directional property; film; orientation; reinforced plastic; sheet; wood.**

tension-recovery chart In tension testing, a continuously plotted graph of tension versus extension resulting from a tension-recovery cycle.

tension set The strain remaining after a test piece or product has been stretched and allowed to retract. See **set; strain.**

tension shrink film The force per original average cross-sectional area that is developed by a film in a specified direction and at a specific temperature in its attempt to shrink while under restraint. See **orientation; orientation, shrink-film; thermoforming, shrink wrapping.**

tension tie The strapping that is applied with mechanical tools. See **strapping tape.**

tension winding See **extruder take-off winder; filament winding.**

tenter frame See **orientation, tenter frame and roll.**

terephthalate An organic chemical that is used in the manufacture of (thermoplastic) linear crystalline polyester plastic films and fibers by combination with glycols. See **crystalline plastic; polyethylene plastic; thermoplastic.**

terpolymer See **polymer, ter-.**

test A determination by technical means the properties and performances of plastics. It should involve the application of established scientific principles and procedures and should specify what requirements are to be met. Testing yields basic information about plastics performance, the properties of materials, quality with reference to standards, finished products, and designing with plastics. Most tests are destructive tests, but some are nondestructive tests. Various types of test equipment are available for the destructive and nondestructive evaluation of materials and products. Tests can characterize plastic properties in the raw material stage, during processing, and in the final fabricated product. Simple to complex tests are used, depending on what is required to be determined or analyzed. Thermal, optical, chemical, mechanical, physical, and electrical tests can be conducted. All kinds of properties are determined, such as density, morphology, molecular structure, and hot melt strength. See **fiber; filament; testing; yarn.** Tests outlined can be conducted on practically any requirement. Many tests are outlined in specifications and standards. Most standardized laboratory tests are at best a simplification or approximation of what may happen to a finished product in use. However, when properly analyzed and applied, tests have been exceptionally functional in producing successful products with all kinds of materials for centuries. See **quality control.** See **computer-aided testing; computer database; creep; design-failure theory; design, safety factor; fatigue; inspection; legal matter: product liability; modulus; quality optimization goal; production performance; quality assurance; reliability; shear; specification; standard; statistical material selection, reliability; test analysis, micromechanical; test data and uniform standards; test, nondestructive; test, organoleptic; thermal analysis; torsion.**

test, abrasion A test that determines the abrasion resistance of materials. For example, the Taber abrasion test measures the weight loss of a plastic or other material after it is subjected to abrasion in a Taber abrader for a prescribed number of specimen disk rotations (usually 1,000) and at a specific setting of weight and type of grit surface used. The abrader consists of an idling abrasive speed-controlled rotating wheel with the load applied to the wheel. The abrasive action on the specimen simulates that of rolling with slip. See **abrasion.**

test, adhesive scotch-tape A method of evaluating the adhesive bond to a plastic substrate. Pressure-sensitive adhesive tape is applied to an area of the adhesive coating, which is sometimes cross-hatched with scratch lines. Adhesion is considered to be adequate if the tape pulls off no coating when it is removed.

test, aircraft canopy Early during the 1930s, the U.S. Navy developed a useful canopy "chicken" impact test that continues to be used with certain modifications. A 4 lb (2 kg) chicken is fired out of a cannonlike device to evaluate and set degree of impact damage. See **impaction.**

test, aluminum wettability The extend to which the residual rolling oil has been removed in the annealing process. The test uses different solutions of ethyl alcohol in distilled water, usually in increments of 10vol%. Also called *foil wettability* or *dryness.* See **wettability.**

test analysis, micromechanical A method for determining the strength and endurance of a material under stress. Moduli, strain, strength, and toughness are measured microscopically. These parameters are useful for material selection and design. Their mechanisms of deformation and fracture are affected by the viscoelastic behavior of plastics. The fracture behavior of materials, especially macroscopically brittle materials, is governed by the microscopic mechanisms operating in a heterogeneous zone at the crack tip or stress initiation area. To supplement macromechanical investigations and advance the knowledge of the fracture process, micromechanical measurements in the deformation zone are required to determine local stresses and strains. In thermoplastics, craze zones can develop that are important microscopic features around a crack tip governing strength behavior. Fracture is preceded by the formation of a craze zone that is a wedge-shaped region spanned by oriented microfibrils. Methods of craze-zone measurements include optical emission spectroscopy, diffraction techniques, scanning electron microscope, and transmission electron microscopy. See **brittle; crack; crazing; fracture; modulus; spectroscopy; strain; stress; testing; viscoelasticity.**

test area See **cleanroom.**

test area reduction The difference between the original cross-sectional area of a tensile test specimen and the area of its smallest cross-section after the test expressed as a percentage of the original.

test, bearing-strength A method of determining the behavior of materials that are subjected to edgewise loads, such as loads applied to mechanical fasteners (plastics, etc.). For plastics, a flat rectangular specimen with a bearing hole centrally located near one end is loaded gradually either in tension or compression. Load and longitudinal deformation of the hole are measured frequently or continuously to rupture, with resulting data plotted as a stress-strain curve. For this purpose, strain is calculated by dividing change in the hole diameter in the direction of loading by the original hole diameter. Bearing stress is calculated by dividing the load by the bearing area and is equal to the product of the original hole diameter and specimen thickness. Test results are influenced by the edge-distance ratio—that is, the ratio between the distance from the center of the hole to the nearest edge of the specimen in the longitudinal direction and hole diameter. See **bearing; stress-strain curve.**

test, biocompatibility See **ISO-10993 certification.**

test, bubble A form of leak test for a closed gas container in which a leak is indicated by the formation of a bubble at the site of the leak.

test, burst Mullen A hydraulic bursting strength test for materials such as films, sheets, and fabrics using a hydraulic diaphragm tester. See **burst strength; punching device; test, impact; test, tear-resistance.**

test, carcinogenicity A test for determining the potential of a device or material that comes in contact with a person to cause or incite the growth of malignant cells (that is, its carcinogenicity). This issue is addressed in the set of biocompatibility standards that were developed as part 3 of ISO-10993, the standard that pertains to genotoxicity, carcinogenicity, and reproductive toxicity. The standard describes carcinogenicity testing as a means to determine the tumorigenic potential of devices, materials, or extracts to either a single or multiple exposure over a period of the total lifespan of the test animal. The circumstance under which such an investigation may be required is given in part 1 of ISO-10993. See **biocompatibility; ISO-10993 certifications test, medical-device compatibility.**

test, cavitation erosion An instrument whose driving frequency is in the ultrasonic range of greater than 20,000 Hz. See **cavitation erosion; ultrasonics.**

test certification A written, printed, or signed document that attests to the validity of the test performed. See **inspection; ISO-9000 certification; ISO-14000 certification; processor certification; productivity.**

test, chemical For many problems, spectroscopic techniques serve to identify unknown plastics rapidly. However, depending on the information sought and the availability of equipment, simple chemical tests may serve as well or better than elaborate instrumental procedures. For example, the way a material burns, solubility or elemental analysis, origin, or price may serve to identify or to allow a choice to be made between one of several materials. See **spectroscopic analysis.**

test, chemical property A material characteristic that relates to the structure of a material and its formation from the elements. These properties are usually measured in a chemical laboratory. They cannot be determined by visual observation. It is usually necessary to change or destroy a material to measure a chemical property. See **chemical analysis; mechanical property; periodic table.**

test, coating electrical-spark An electrical test in which a spark is used to detect discontinuity of a coating.

test, cold-bend A test that measures the flexibility of elastomeric plastics at low temperatures that simulate the conditions intended for its use. See **bend test; flexural property.**

test, color A quantitative analysis of a substance that compares the intensity of the color produced in a sample by a reagent with a standard color produced in a solution of known strength. See **colorimeter; color standard; test, organoleptic.**

test compliance A term that is used in the evaluation of stiffness and deflection. **1.** The reciprocal of Young's modulus. See **coefficient of elasticity. 2.** The reciprocal of shear modulus.

test, compression-property Most tests that evaluate characteristics of plastics are performed in tension or flexure; thus, compressive stress-strain behavior is not well described for many plastics and not usually necessary for evaluation. Generally behavior differences in compression and tension of their stress-strain response can be considered negligible and so are neglected. For example, tensile secant modulus may be used, and generally the compression modulus is reported as an initial modulus. This determines the behavior of a material that is subjected to a uniaxial compressive load at a controlled speed until it fails. Load and deformation measurements are made so that a stress-strain diagram can be obtained. The S-S diagram determines ultimate strength, elastic limit, modulus of elasticity, proportional limit, and yield strength. See **compression plane strain; elastic stability; loading edgewise; modulus, secant; modulus, tension; stress-strain curve; stress-strain measurement; testing.**

test condition See **service condition.**

test, conductivity In evaluating the electrostatic discharge of plastics, volume and surface resistivity, electrical resistance, and static decay rate tests are conducted. These tests are also conducted for electromagnetic interference and radio-frequency interference shielding material, and in addition they are subjected to a shielding-effectiveness test. See **electrical conductivity; electrical surface resistivity; electrical-volume resistivity; electromagnetic interference; electromagnetic interference, shielding-effectiveness of; insulation resistance; static; static decay rate.**

test, consumer and flavor See **test, organoleptic.**

test, container column crush A measure of resistance of a plastic container to deformation under a vertical load that is applied along the container's vertical axis.

test coupon A specimen for a specific test. Also called *test specimen.* See **test method.**

test, crack-growth-resistance In the Di Matteo Flexing Machine Test, crack-growth resistance may be expressed as the number of cycles needed under repeated bend flexing to reach a specified crack length or rate of cracking during a specified portion of the test. See **crack growth; fatigue; fracture.**

test, creep See **designing with creep data.**

test, cup-flow A test in which plastic is fed into a specified sized mold cavity and the mold is closed under specified pressure. The time it takes for the mold to close completely, expressed in seconds, is the cup-flow value. See **test, melt-flow.**

test, curing plastic See **flow; test, hardness Barcol; test, plastometer melt-flow.**

test data and uniform standards For the initial selection of plastic materials, single-point data values are acceptable (generally they are the only ones available). For applications over given ranges of property requirements (based on product performance requirements), the functional dependency of properties need to be determined based on factors such as time, temperature, and static and dynamic load measurements. Practically all properties reported on a technical data sheet are so-called standard static test conditions, typically at room temperature. In the real world when precision and extreme accuracy is required, property results achieved in one laboratory may not match those obtained in another laboratory. Fabrication and preparation of test specimens, method of running a specific test (grip, speed, etc.), and other factors can cause results to differ. See **computer software; design technology; dynamic analysis; plastic material selection; specification; standard; statistical material selection, reliability of; temperature, room; test; test method.**

test, deflection temperature under load (DTUL) The temperature at which a sample cantilever beam deflects a given amount under load under specific testing conditions. DTUL can be used as a guide with proper interpretation. Also called *distortion temperature.* See **annealing; flexural strength; heat deflection temperature; test, heat; distortion-point; test, Martins temperature.**

test, deflection temperature under load versus crystallinity A high degree of crystallinity, as in HDPE, PP, and nylon, has little or no effect on the rigidity of the glassy amorphous state at low temperatures and only minor effect on the phenomenon of their glass transition. But it introduces so much stiffening into the flexible state that it becomes quite tough and rigid. This behavior extends to much higher temperatures until a true crystalline melting occurs quite sharply to a fluid liquid state. See **glass transition.**

test, degree of If a failure of a part could be catastrophic to life, then extensive and usually expensive testing is necessary. If only a certain weight of the part is required, then that test is all that needs to be performed. Where large production runs of products are being made, extensive testing is required of the raw plastic materials and equipment operations.

test, designated No single set of rules designates which tests are to be conducted to manufacture a part repeatedly with zero defects. The tests depend on the required performance that is usually set by the customer. There are many standard, industry-accepted tests that are conducted on raw materials such as the melt-index tester and other rheological test equipment that can be used as the melting occurs during fabrication. For example, there are practically an unlimited number of ways to run dimensional tests during fabrication.

test, destructive A test that destroys the samples or products. See **test, nondestructive.**

test, dielectric A test that consists of the application of a rated voltage for a specific time to determine the adequacy against breakdown of insulating materials under normal operating conditions. See **dielectric; test, nondestructive electrical; test, nondestructive electrical eddy current.**

test, electrical eddy current See **test, nondestructive electrical eddy current.**

test, fatigue S-N diagram See **fatigue S-N diagram.**

test, fire cone and lift UL uses several tests to obtain fire-performance data. The response of a material to fire involves a variety of parameters, including heat-release rate, smoke-density rate, time to ignition, and lateral flames spread. The cone calorimeter which tests for heat and visible-smoke release rate is named for the electrical heater rod that is wound into the shape of a truncated cone. Rate of heat release is the primary measurement obtained and probably the most important fire-performance measurement, since almost all of the other processes involved in fire development are driven by heat-release rate. The lift test is used for the two procedures of measuring ignition and lateral flame spread. See **fire; ignition temperature; Underwriters' Laboratory fire-resistance index.**

test, fire tunnel A test that provides a comparative assessment of the surface burning characteristics of materials on a relatively large scale. Different results are reported. Important data are the flame spread distance versus time on materials to determine the flame spread index. It is 0 for incombustible cement-asbestos board and 100 for red oak. Values below 25 are materials normally rated as incombustible, 25 to 50 as fire resistant, 50 to 75 as slow burning, 75 to 200 as combustible, and over 200 highly combustible. Also called the *Steiner tunnel test.* See **fire; flammability; limiting index oxygen; test, flame spread index; Underwriters' Laboratory.**

test, flame spread index (FSI) A number classification indicating a comparative measure derived from observations made during the progress of the boundary of a zone flame under defined test conditions (ASTM E-84). See **test, fire tunnel.**

test, flexometer A machine that subjects a test specimen to a cyclic deformation load that may be in compression, tension, flexural, or shear.

test, foam-pressure A test that measures pressure, rise height, and temperature and that simulates the foaming action during processing. For example, pressure measurement is valuable for analyzing rigid foams used in cavity filling. Also for molded foams where the pressure versus time curve helps determine when to open the mold for the shortest cycle time without cracking the foam. See **foam.**

test, force-extension Force-strain is usually called *stress-strain.* The plot or curve that develops depends on the rate of extension, the ambient temperature, the type of plastic, and its molecular state. From the low-extension region of such curves, various moduli can be derived, such as from the terminal region (strength), from the overall shape of the curve (ductility) and inferences on the potential utility of the material. Thus, much useful information can be derived from what is a simple test. However, there are limitations to the data that stem from this simplicity and that apply to the complexity of plastic materials such as their viscoelasticity. See **modulus; molecular structure; stress-strain curve; viscoelasticity.**

test, fusion Kling A method for determining the relative degree of fusion of flexible PVC sheets, coated fabrics, and thin sections of cast or molded parts by immersing the folded specimen in a solvent and noting the time it takes for disintegration to occur. Typical solvent systems use MEK, ethyl acetate, and carbon tetrachloride. The preferred system is one that will initiate degradation within 5 to 10 min on a fully fused specimen. See **coating.**

test, hardness Barcol A test that measures the hardness of a plastic by using a Barber Coleman spring-loaded indenter. It gives a direct reading on a 0 to 100 scale, with a higher number indicating greater hardness. This test is often used to measure the degree of cure for plastics, particularly, thermoset plastics. Also called *Barcol impresser.*

test, hardness Brinell A common test that is used to determine the hardness of a material by indentation of a specimen. Pressing a hardened steel ball generally 10 mm diameter down on a specimen carries out the test, and the diameter of the impression that is formed provides a basis for calculating hardness.

test, hardness Knoop A test that measures hardness by a calibrated machine that forces a rhombshape, pyramidal diamond indenter having specified edge angles under specific small loading conditions into the surface of the test material; the long diagonal in the material is measured after removal of the load.

test, hardness Mohs A measure of the scratch resistance of a material. The higher the number, the greater scratch resistance, with number 10 being termed diamond.

test, hardness Rockwell A number that is derived from the net increase in the depth of an impression as the load on an indenter is increased from a fixed minor load (10 kgf) to a major load and then returned to the minor load. This number consists of the number of scale divisions, each corresponding to 0.002 mm vertical movement of the indenter. Rockwell scales, designated by a single capital letter of the English alphabet (e.g., Rockwell M., Rockwell R.); vary depending on the diameter of the indenter and the major load.

test, hardness scleroscope A dynamic indentation hardness test using a calibrated instrument that drops a diamond-tipped hammer from a fixed height onto the surface of the material being tested.

test, hardness Shore A test of the indentation hardness of a material as determined by the depth of an indentation made with an indenter of the Shore-type durometer. The scale reading on this (scelroscope) durometer is from zero (corresponding to 0.100 in. depth) to 100 for zero depth. The Shore A indenter has a sharp point, is spring-loaded, and is used for the softer plastics. The Shore B indenter has a blunt point, is spring-loaded at a higher value, and is used for harder plastics.

test, hardness Vicat A determination of the softening point for thermoplastics that have no definite melting point. The softening point is taken as the temperature at which the specimen is usually penetrated to a depth of 1 mm^2 (0.0015 $in.^2$) circular or square cross section, under a 1,000 g load.

test, heat distortion-point The temperature at which a standard test bar deflects 0.010 in. under static load either at 66 or 264 psi with the temperature increasing 2°C/min. See **elastic memory; deflection temperature under load versus crystallinity; testing.**

test, heat pendulum Wiegand An apparatus that demonstrates the Gough-Joule effect. It includes a pendulum so that an elastomer or rubber material is loaded under stretch conditions. Heat from a lamp causes the material to contract and swing the pendulum. This action pulls the material into a shaded area, where it extends and moves the pendulum back to the original position, whereupon the cycle repeats. See **elastomer; heat effect, Gough-Joule; rubber.**

test, impact A type of test for shock loading where the energy that is required to cause complete failure is reported. Tests include ball or falling dart using different weights and heights, bullet-type instantaneous impacts, and pendulum types. See **automobile bumper fascia; energy absorption; impaction; joule; test, burst Mullen; test, nondestructive impact RP coin tapping; test, tear-resistance.**

test, impact bag-drop Film impact strength can be determined by several different methods. In the bag drop test, materials (sand, beans, golf balls, etc.) are dropped from a specific height onto a film that is on a smooth, hard surface. The maximum height that the bag will sustain three successive drops without bursting serves as a measure of the film's impact strength. Variations of this test are used to end-use requirements, such as film that is clamped into a frame so that contact is made only on the free-moving film, a bag that contains water or film that is frozen. See **packaging, grocery-bag.**

test, impact ball-burst film Pendulum impact resistance determines film toughness. The force required to rupture the film is indicated on a scale. See **toughness.**

test, impact Charpy A centrally notched (or unnotched) sample bar is held at both ends and broken by striking the back face in the same place as the notch.

test, impact coin See **test, nondestructive impact RP coin tapping.**

test, impact dart-drop There are several types of falling-dart specification tests for plastic films or rigid parts. In each of these tests a weight is dropped from a tower onto a specimen. The usual steel weight, known as a *tub* or *falling dart*, is usually cylindrical with a rounded nose that contacts the specimen. Specimens can be on a support frame or clamped to a metal ring. The amount of weight and the drop height are varied until half (or more in special tests) of the specimens break. See **toughness.**

test, impact Gardner A falling ball-impact test that utilizes the kinetic energy of a free-falling projectile to assess the impact resistance of a plastic. The energy is varied incrementally by changing the dart weight and drop height. Specimen failure is defined as a visible crack on the underside of the specimen. Typical units of energy are joule (J) or foot-pound (ft-lb).

test, impact Izod The energy that is required to break a smooth or a V-notched specimen that is equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact with the specimen and the energy remaining after complete fracture of the specimen. Also called *Izod impact energy*.

test, impact loading-rate Comparisons strain rates versus deformation of materials can be made where energy losses occurring can be related to impact strength. The value of impact strength is influenced by various factors, such as contained residual strains, degree of molecular crystallization, increases with increasing temperature (especially in the region of glass transition temperature), and type of impact device. Tests include creep and stress rupture, static, rapid, and different impact devices where strain rates range from 10^{10} to 10^{4} in./in./s.

test, impact notch-factor The ratio of the resilience determined on a plain specimen to the resilience determined on a notched specimen. See **energy absorption; notch sensitive.**

test, impact reverse One side of a sheet is struck by a pendulum or falling object, and the reverse side is inspected for damage.

test, impact tensile Similar to the Izod impact test except a tensile specimen is clamped into a fixture attached to a swinging pendulum. The swinging pendulum is released from a predetermined height and strikes a stationary anvil causing the sample to rupture. Energy absorbed is reported.

test, impact tub A falling weight (tub) impact test developed for pipe and fittings.

test, infrared A technique in which a sample is irradiated with electromagnetic energy from the infrared region of the electromagnetic spectrum (wavelength −0.7 to 500 mm). It produces an absorption spectrum or "fingerprint" of the material. It is commonly used to identify plastics, additives, and coatings. See **infrared; inspection, infrared; test, nondestructive temperature differential by infrared.**

test, iodine value The number of grams of iodine absorbed by 100 g of fat or oil. The test gives an indication of the degree of unsaturation.

test jaw The elements of a clamping system that grips the test specimen. The grip design and grip load that are applied to the sample can have a direct influence on the repeatability and validity of test results and the outcome of test data. Simple rules that are given in specifications exist on how to eliminate any major problems.

test laboratory A laboratory that measures, examines, tests, calibrates, or otherwise determines the characteristics or performance of materials and products.

test laboratories, worldwide approval of A U.S. government directory lists the various labs and forms of testing that are endorsed by the National Voluntary Accreditation Program. It is available from National Institute of Standards and Technology, NVLAP Directory, A124 Building, Gaithersburg, MD 20899. See **government contract directory.**

test, laminated curved-bar delamination analysis A potential cause of stiffness or strength degradations in laminated or reinforced plastics is the delamination between their layers. One of the most appealing geometries of a test sample for studying this phenomenon is a semicircular curve bar shape (C-shape). When such a test specimen is subjected to end forces, the peak radial stress and the peak shear stress induced will be identical in magnitudes but are out of phase in the tangential direction by $\pi/2$. The peak radial stress is located at midspan point of the semicircular curved bar, but the peak shear stresses occur at both ends. The radial distance of both the peak radial stresses and the peak shear stresses are exactly the same. This test permits studying the initiation and subsequent propagation of delamination zones. See **laminate; reinforced plastic; strain, flexure of fiber.**

test, leakage See **container leakage.**

test, least count The smallest change occurring in test results that can customarily be determined and reported.

test, LOX mechanical-impact-sensitivity See **polyarylene ether phosphine oxide plastic.**

test machine, constant rate See **tensile testing-machine test rate.**

test machine, universal A machine that performs different tests, such as tensile, compression, flexural, or shear tests.

test, Maxwell-Wagner effect The effect on dielectric properties that is caused by discontinuities or inclusions in the dielectric. This results in interfacial polarization and the occurrence of a dielectric relaxation at low frequency. In some cases, the relaxation may be at a frequency that is high enough to be caused by a dipolar relaxation, so some care must be taken in the interpretation of test results. The heterogeneity may be a crack or void of a crystalline or amorphous boundary or a highly conductive impurity that is present in the insulating plastic dielectric. See **dielectric.**

test, medical-device compatibility The tripartite biocompatibility guidelines for medical devices were introduced by the medical-device authorities of the United States, United Kingdom, and Canada. They established an approach for the evaluation of the toxicity of medical devices. See **hemocompatibility; ISO-10993 certification; medical material and the environment; test, carcinogenicity.**

test, melt-flow Various test methods are used to characterize plastics for high shear melt processing. Some tests relate directly to commercial processing, and others have little or no relationship to a specific process. The major method used is the melt index. The most exact method for improving quality and process control is the rheometer type. General characterization of flow behavior is offered by the steady shear test, such as a capillary viscometer or a rotational rheometer. However, some tests are conducted with a variable force. See **melt flow; test, cup-flow; testing; test, melt index; test, melt rheometer.**

test, melt-flow Brabender plasticorder rheometer An instrument that continuously measures the torque exerted in shearing a thermoplastic, thermoset, or compounded material over a wide range of shear rates and temperatures, including those conditions anticipated in actual manufacturing. It records torque, time, and temperature on a graph called a *plastogram*, from which much information can be obtained with regard to processability of the plastic. It shows the effect of additives and fillers and measures and records lubricity, plasticity, scorch, cure, shear, heat stability, and plastic consistency.

test, melt-flow Canadian A method of determining the rheology or flow properties of thermoplastics. It was developed by Canadian Industries, Ltd. (CIL). In this test, the amount of melt that is forced through a specified-size orifice per unit of time when a specified, variable force is applied gives a relative indication of the flow properties of the plastic.

test, melt flow plastometer An instrument for determining the flow properties of a thermoplastic by forcing the melt through a die or orifice of specific size at a specified temperature and pressure. See **flow; rheometer; viscometer.**

test, melt-flow Rossi-Peakkes An instrument that is designed to measure the temperature at which a definite amount of plastic will flow through a special orifice when subjected to a prescribed constant pressure.

test, melt-flow spiral A method for finding the flow properties of either thermoplastic or thermoset plastics that formulates the distance the plastic will flow under specified pressure and temperature along a spiral runner in a mold. The test is usually performed using injection molding for thermoplastics. With thermosets a compression or transfer molding press may also be used. Plastic is fed into the center of the mold where the spiral starts. Under specifically controlled molding conditions, the length of the plastic's melt that flows into the cavity and its weight provide an indication of the flow properties. It is more popular with thermoset plastics. See **compression molding; injection molding; test, molding index; test, thermoset flow; transfer molding.**

test, melt-index (MI) A low-cost, easy-to-operate, widely used test that is basically a ram extrusion plasticator. This so-called rheological device is used for examining and studying thermoplastics in many different fabricating processes. It is not a true viscometer, since a reliable value of the viscosity cannot be calculated from the flow index. However, it does measure isothermal resistance to flow using an apparatus and test method that is standard worldwide. In this instrument the unmelted-solid plastic is contained in a "barrel" with a temperature indicator. An electrically controlled heater that melts the plastic basically surrounds it. A weight drives a plunger that forces the melt through the die opening; the orifice is usually 0.0825 in. (0.2096 cm) in diameter when subjected to a force of 2,160 g at 190°C. The usual procedure involves the determination of the amount of plastic extruded in 10 min (after initial flow starts). The flow rate is expressed in g/10 min. More than one test is conducted, and in turn an average is reported. As the flow rate increases, the viscosity decreases.

This MI makes a single-point test that provides information on the resistance to flow only at a single shear rate. Note that the extruder normally requires a low MI when compared to injection molding, since it requires melt strength when extruding into "open" space, whereas IM is forced into a closed mold. Because variations in branching or molecular-weight-distribution of the plastic can alter the shape of the viscosity curve, the MI may give a false ranking of plastics in terms of their shear rate resistance to melt flow. To overcome this situation, extrusion rates are sometimes measured for different loads and other modifications are made to the instrument, such as changing the size of the orifice. Also called *MFI, melt-flow rate, melt-flow index*, or *base resin melt index*. See **blow molding, extruder, plastic melt index; injection molding, programmed; melt flow; rheometer; test, melt-index; test, melt rheometer; viscosity.**

test, melt index, fractional Thermoplastics have a low melt index of <1. These plastics have higher molecular weights and are more difficult to process (extrude, etc.) because of their lower rate and greater force requirements compared to the lower-molecular-weight plastics. They are mainly used where exceptionally high performance requirements exist. See **thermoplastic.**

test, melt rheometer For a "real" method to characterize plastic's melt behavior the capillary melt rheometer is used. It is fully automated and covers a wide range of shear rates. When used online with extruders many operating benefits are gained such as improving or ensuring quality, reducing scrap, and lowering costs. This instrument is far superior in understanding melt behavior than others. See **rheometer, capillary online; test, melt-index.**

test method A definitive, standardized set of instructions for the identification, measurement, or evaluation of one or more qualities, characteristics, or properties of a material. Test methods differ in the degree to which they accurately and precisely assess the properties. Refinements are made as their inadequacies have been exposed. Inadequacies in the data can arise more from deliberate attempts to limit the escalating costs of testing. The tests are satisfactory when they are used strictly within limits that are defined by their testing features and the nature of the plastics. Any interpretation should always be documented with an explanation as to why it was made. See **practice; test data and uniform standards; test specimen.**

test method conformance The agreement of the properties of a sample or lot with specification requirements. See **quality control.**

test, microdynamometer An instrument for measuring mechanical force and observing the change in microscopic appearance of a small specimen.

test, microtoming optical-analysis In this procedure thin slices (under 30 μm) of the plastics are cut from the part at any level and microscopically examined under polarized light transmitted through the sample. Rapid quality and failure analysis examination occurs by this technique. This technique has been used for many years in biological studies and by metallurgists to determine physical and mechanical properties. Examination can be related to stress patterns or mechanical properties. See **birefringence; inspection infrared; polarized light; porosity; strain, residual; test, nondestructive photoelastic stress-analysis.**

test, moisture-content reinforced plastic In addition to the usual physical moisture-content determination tests, electrical systems are used. For example, in unidirectional reinforced plastics, the normalized change in resistance is measured and found to vary with the square of the moisture content. For multidimensional RPs, a different method is used. A modified, four-terminal method utilizes resistance of electrical contacts, which eliminates error. Resistance measured across the thickness is linearly proportional to the moisture content. See **moisture content; test, water-absorption.**

test, molding index A test that is used with thermoset plastics where a standard flash-type cup mold under prescribed processing conditions is used. The molding index is the total minimum force that is required in closing the mold. See **test, spiral melt-flow; test, thermoset flow.**

test, viscosity Mooney A measure of the viscosity of a plastic determined in a Mooney shearing disk viscometer. See **nitrile rubber; viscometer.**

test, NOL ring A parallel filament wound tensile hoop test specimen of a specific diameter such 15 cm (developed by Bob Bennett at Naval Ordnance Laboratory in the 1950s) provides a simple means to conduct mechanical tests. See **ABL bottle; filament winding; reinforced plastic; shear strength, short-beam; stress, hoop.**

test, nondestructive (NDT) In destructive testing, the original configuration of a test specimen (product) is changed, distorted, or even destroyed for the sake of obtaining such information as the amount of force that the specimen can withstand before it exceeds its elastic limit and permanently distorts (usually called *yield strength*) or the amount of force needed to break it (the *tensile strength*). These data are quantitative and can be used to design structural parts that would withstand a certain oscillating load or heavy traffic usage. However, one could not use the test specimen in the part. One would have to use another specimen and hope that it would behave exactly the same as the one tested. Nondestructive testing, on the other hand, examines without impairing ultimate usefulness. It does not distort the specimen but provides different types of data. NDT allows suppositions about the shape, severity, extent, distribution, and location of such internal and subsurface defects as voids, shrinkage, and cracks. NDT methods include acoustic emission, radiography, infrared spectroscopy, x-ray spectroscopy, magnetic resonance spectroscopy, ultrasonic, liquid penetrant, photoelastic stress analysis, vision system, holography, electrical analysis, magnetic flux field, manual tapping, microwave, and birefringence. See **computer-aided testing; computer-aided tomography; liquid, elastic; nondestructive test, proof load.**

test, nondestructive acoustic emission When flaws or cracks grow in plastic, minute amounts of elastic energy are released and propagated in the material as an acoustic wave. Sensors placed on the surface can detect these waves and provide information about location and rate of flaw growth. These principles form the basis for nondestructive test methods such as sonic testing. See **mathematical acoustic impedance; test, nondestructive impact RP coin tapping.**

test, nondestructive acoustic-holography A technique that permits rather precise observation of dimensional deviations from the reference configuration, so that anomalies can be located. Computer reconstruction provides the means for storing and integrating several holographic images. A reconstructed stored image is a three-dimensional picture that can be electronically rotated and viewed in any image plane. The images provide full characterization and detail of buried flaws. This technique has been applied to nondestructive inspection of reinforced plastics and other structures. The structure is mounted on a stable platform and is then subjected to a stress condition, either thermal or mechanical. See **holography; inspection; test, nondestructive evaluation; test, nondestructive ultrasonic.**

test, nondestructive carbon-fiber reinforced plastic x-ray scanning Carbon fibers generally exhibit an inhomogeneous and anisotropic arrangement of their components. Traditional methods of nondestructive testing, such as ultrasound, radiography, and electrical eddy current techniques, have their place but often give less than satisfactory results; also optical and thermal methods have only limited depth of penetration. X-ray techniques allow the material specific detection of a variety of substances. With carbon fiber reinforced plastics (CFRPs), the layers with uniform fiber orientation can be selected and identified. It provides any three-dimensional examination of the interior of a specimen that is in contrast to computer-aided tomography. It is possible to study not only crystalline plastic substances but also those that produce diffuse x-ray reflexes. This group includes carbon fibers, plastics, and glass. See **crystalline plastic; fiber, carbon; reinforced plastic.**

test, nondestructive curing See **thermoset plastic curing, electromagnetic.**

test, nondestructive electrical With nondestructive testing, the dielectric constant and dissipation factor (or loss tangent) can be used for determining variability in filled plastics. See **test, dielectric.**

test, nondestructive electrical eddy current A method in which eddy current flow is induced in the test object. Changes in the flow by variations in the test specimen are reflected into a nearby coil or coils for subsequent analysis by suitable instrumentation and techniques. See **electrical eddy current, standard depth of penetration in the.**

test, nondestructive electromagnetic A nondestructive test for materials, including different wavelength regions, that use electromagnetic energy having frequencies less than those of visible light to yield information regarding the quality of materials. See **electromagnetic spectrum.**

test, nondestructive evaluation (NDE) Considered synonymous with nondestructive inspection (NDI). More specifically, the analysis of NDI findings is to determine whether the material will be acceptable for its function.

test, nondestructive impact RP coin tapping The use of a coin (such as a half dollar) to tap a reinforced plastic or laminated structure in different spots to detect a change in sound that would indicate the presence of a defect, such as a delamination, void, or uncured RP. This is a surprisingly accurate impact type test in the hands of experienced personnel. It started during the 1940s and 1950s when large RP radomes were fabricated. It was extensively and successfully used at the time since acoustical test equipment was not available. See **laminate; reinforced plastic; test, impact; test, nondestructive acoustic emission.**

test, nondestructive inspection (NDI) The process or procedure, such as ultrasonic or radiographic inspection, for determining the quality or characteristics of a material, product, or assembly without permanently altering the subject or its properties. See **inspection; inspection, visual; test, nondestructive acoustic holography.**

test, nondestructive moire fringe analysis A test that is used for flat surfaces that are not readily conducive to stress evaluation by other means. Measurements of strains both elastic and plastic as well as evaluation of high temperature effects on the part are possible. A transparent film with a grid of equidistant lines is initially deposed on the part. Deformation in the part due to stresses changes the spacing between the grid lines. When a test grid is superimposed on a nondeformed grid, the superposition produces an optical effect known as *moire fringes.* If the test part is not strained and the grids are precisely aligned, no fringes will be observed. Visible fringes can be precisely measured to determine the degree of strain in a part. See **deformation; strain; stress.**

test, nondestructive photoelastic stress-analysis A technique for the nondestructive determination of stress and strain components at any point in a stressed product by viewing a transparent plastic product or, if not transparent, a plastic coating, such as certain epoxy, polycarbonate, or acrylic plastics. This test method measures residual strains using an automated electrooptical fast system. This concept has been known for over a century. Expressed as Brewster's constant law, it states that the index of refraction in a strained material becomes directional, and the change of the index is proportional to the magnitude of the strain present. Therefore, a polarized beam in the clear plastic splits into two wave-fronts that contain vibrations oriented along the directions of principal strains. An analyzing filter passes only vibrations parallel to its own transmitting plane. The constructive and destructive interference creates the well-known colorful patterns seen when stressed plastic is placed between two polarized filters. Some information about the strain gradients comes from observations of the patterns that provide qualitative analysis.

To solve the measurement problem and obtain quantitative results (retardation, magnitude of the residual strain, etc.), various techniques are used. An example is using a very simple device known as a wedge compensator (ASTM D 4093). It is placed between the light coming through the sample and the analyzing filter. The compensator reverses the retarding action of the induced strains in the plastic. Strain is calculated in the compensator by multiplying the birefringence (retardation per unit thickness) by a strain-optic response of the plastic being tested. Equal but opposite retardation is established and, when superimposed on the retardation caused by the induced strain, restores a null. The intensity of the transmitted light becomes zero. It is revealed by a visible black fringe. A scale on the compensator supplies a quantitative reading of retardation. See **birefringence; infrared inspection; light index of refraction; orientation and optical property; photoelasticity; polariscope; polarized light; strain, residual; test, microtoming optical analysis; test, nondestructive temperature differential by infrared; test, residual-stress.**

test, nondestructive-radiography A frequently used test where x-rays or gamma rays passing through a structure are absorbed distinctively by flaws or inconsistencies in the material so that cracks, voids, porosity, dimensional changes, and inclusions can be viewed on the resulting radiograph. See **digital imaging; test, nondestructive stress-strain measurement, brittle lacquer technique.**

test, nondestructive residual strain See **test, nondestructive photoelastic stress-analysis.**

test, nondestructive stress-strain measurement, brittle lacquer technique A test that provides experimental quantitative stress-strain measurement data. A brittle coating is sprayed on a part. As the part is loaded in proportion to loads that would be encountered in service, cracks begin to appear in the coating. The extent of cracks is noted for each increment of load. Prior to this action, the coating is calibrated by spraying it on a simple beam and observing the strain at which cracks appear. This nondestructive test method can be used to aid in placing strain gauges for further measurements. See **photoelasticity; stress-strain curve; test, nondestructive radiography.**

test, nondestructive temperature differential by infrared In this method, heat is applied to a part, and the surface is scanned to determine the amount of infrared radiation that is emitted. Heat may be applied continuously from a controlled source, or the part may be heated prior to inspection. The rate at which radiant energy is diffused or transmitted to the surface reveals defects within the part. Delaminations, unbonds, and voids are detected in this manner. This test is particularly useful with reinforced plastics. See **inspection, infrared; test, nondestructive photoelastic stress-analysis; void.**

test, nondestructive transparent medium light schlieren Regions of varying refraction in a transparent medium that are often caused by pressure and temperature differences and are detectable especially by photographing the passage of a beam of light. See **transparent.**

test, nondestructive ultrasonic The back and forth scanning of a specimen with ultrasonics. This nondestructive testing technique can be used to find voids, delaminations, and defects in fiber distribution. In ultrasonic testing the sound waves from a high-frequency ultrasonic transducer are beamed into a material. Discontinuities in the material interrupt the sound beam and reflect the energy back to the transducer, providing data that can be used to detect and characterize flaws. It can locate internal flaws or structural discontinuities by the use of high-frequency reflection or attenuation (ultrasonic beam). See **fiber; laminate, de-; reinforced plastic; ultrasonics; void.**

test, nondestructive ultrasonic penetration A relative term denoting the ability of an ultrasonic testing system to inspect material exhibiting high absorption or scattering. See **inspection.**

test, nondestructive visual See **computer image-processor; inspection, vision system.**

test, optical See **test, microtoming optical analysis.**

test, organoleptic A consumer testing procedure that is used for food products, plastics, perfumes, and wines, in which samples of various products, flavors, or colors are submitted to groups or panels. Such tests are a valuable aid to determining the acceptance of products and thus may be viewed as a marketing technique. They also serve psychological purposes and are an important means of evaluating the subjective aspects of taste, odor, color, and other related factors. The physical and chemical characteristics of foods are stimuli for the eye, ear, skin, nose, and mouth, while receptors initiate impulses that travel to the brain, where perception occurs. See **color standard; odor; packaging, food; polypropylene plastic; test, color; testing.**

test, oxygen gas transmission rate (OGTR) An important test for food packaging. Measuring the oxygen through film and sheet can be done with a coulometric sensor following the protocols of ASTM D-3985. Results are reported in $cm^3/m^2/day$ at 23°C (73°F). Also called O_2GTR. See **barrier plastic; packaging, food; packaging, oxygen-scavenger food; permeability.**

test, peel See **adhesive peel strength; bond**

strength; reinforced plastic peel ply; sandwich peel torque; strength, pull.

test, permeability An instrument test for the measurement of the water-vapor transmission rate or gas-transmission rate at which these permeate through film. See **coefficient of gas permeability; coefficient of permeability; test, water-vapor transmission rate; water; water-vapor transmission.**

test, phenol Gibbs indophenol A test for detecting the presence of phenols in finished plastic products.

test, plastic stability See **metastable.**

test, processing See **processing via fluorescence spectroscopy.**

test, product weight Controlling product weight tightly permits better control of part performance and cost. Both overweight and underweight can pose defect problems and undue costs. See **cost, product.**

test, proof A test of a part or system at its peak operating level to assess its performance requirements, such as load or pressure.

test, prototype See **laser sintering, selective; modeling; prototype.**

test, residual-stress A thin layer of plastic is removed by chemical action. It is used to evaluate stresses in the flat specimen. Relieved by the strains in that layer, the remaining specimen curves proportionately so that the residual stress in the removed layer can be calculated. The sample is sectioned into small elements, thus freeing them from balancing stresses. A $^1/_{16}$-in. hole is drilled at the center of a rosette composed of three strain gauges cemented to the desired area. From measurements in the relieved strains around the hole, the residual strain at the center of the gauge can be calculated. See **adhesive, solvent; light index of refraction; stress, residual; test, microtoming optical analysis; test, nondestructive photoelastic stress-analysis.**

test sample See **risk, acceptable; sampling; sampling plan; sampling size; test specimen.**

test, scorch Mooney The time to incipient cure of a compound when tested in the Mooney shearing disc viscometer under specific conditions. See **cure.**

test set, immediate The deformation found by measurement immediately after the removal of the load causing the load. See **elongation, set at break; set.**

test, short-time-behavior A test of the behavior and response of material under loads lasting usually only a few seconds or minutes up to a maximum of 15 minutes. Such short-term tests are used to define the basic or reference designing and engineering stress-strain properties of materials (tensile, compression, flexural, shear, etc.).

test, soap-bubble A type of pressure testing in which the tracer gas is detected by bubbles formed in a layer of soap solution applied to the surface of the test object. See **container leakage.**

test, softening point Vicat The temperature at which a flat-ended needle of 1 mm^2 circular or square cross-section penetrates a thermoplastic specimen in a silicone fluid bath to a certain depth, such as 1 mm, under a specific load using a uniform rate of temperature rise. It is used with polyethylenes which have no definite melting point (crystalline type). See **softening point.**

test, sonic Test methods range from the relatively unsophisticated tapping coin test to the sophisticated ultrasonic testing. See **test, nondestructive acoustic emission; test, nondestructive impact RP coin tapping; test, nondestructive ultrasonic.**

test, spark See **test, electrical-spark coating.**

test specimen A specimen for a specific test. Also called *test coupon.* See **test; test method.** The presence of water in a test specimen represents a common problem that frequently can distort test results or produce unreliable or unrepeatable results. Water may exist as a contaminant from the atmosphere or from a solution in which the substance was formed, or it may be bonded as a chemical compound (hydrate). Regardless of its origin, water plays an important part in determining the composition of the sample. If the moisture is considered detrimental, test procedures exist that specify procedures for the standardization of the specimen by exposing specimens to temperature and humidity conditions for prescribed periods of time, etc. See **test sample.** Test results also can vary if test specimens have been subjected to different melt flow and orientation conditions during processing, even though they were within the process-control requirements. Records should be kept on how the specimens were prepared, which machine was used, and who its operator was. Test results can be compared based on processing parameters. See **fabricating; process control.**

test, stiffness Clash-Berg A test that measures apparent modulus of rigidity over a wide temperature range by torsional means. See **physical property; qualitative analysis; test, chemical property; testing and classification.**

test, stress-strain curve See **stress-strain curve.**

test, tear-resistance A popular test that is performed on film and thin sheet. The Elmendorf pendulum ASTM D-1922 test is performed in both the machine and transverse directions. Directional tear strengths are reported in grams. The tear ratio, TD/TM, is unitless. See **punching device; tear failure; test, burst Mullen; test, impact.**

test, temperature Martins A measure of the softening temperature of a plastic. Plastic is heated at a determined rate and bends to a certain extent under a defined load. It is similar to the heat-distortion temperature but gives a somewhat different result. In the Martins test, it is the temperature at which a flexural bar specimen deflects by a specific amount under a four-point bending load and subjected to a specified bending stress. The bending is magnified by the use of a loading arm attached to the upper end of its vertically mounted specimen. See **test, deflection temperature under load versus crystallinity.**

test, tensile See **tensile analysis; tensile testing machine.**

test, thermal See **thermal aging, relative thermal index; thermal analysis.**

test, thermo See **thermogravimetric analysis.**

test, thermoset flow In Disc Flow I, a measured quantity of plastic, usually used for compression molding, at room temperature is compressed between two die plates at a specific pressure and temperature. The resultant molded disc is measured in thickness to determine flow. The thicker the disc, the stiffer the flow. The same procedure is used in Disc Flow II, except the diameter is compared to the diameter of five different-size concentric rings. The larger the disc, the softer the flow. See **test, molding index; test, spiral melt-flow.**

test, torsional A test of how a material behaves when subjected to twisting loads. A cylindrical specimen with a straight reduced section and longitudinal gauge marks is twisted axially to rupture. A torque-twist diagram is plotted that is analogous to a stress-strain diagram. Properties that can be determined include elastic limit, maximum torsional deformation, modulus of rigidity/elasticity, proportional limit, torsional strength, yield point, and yield strength. The torsion test is sometimes used in preference to the tension test for brittle materials. For large strains, torsion data are considered more valid than tension tests and are often used in the solution of certain mechanical design problems involving shear loading. See **damping index; temperature flexibility, plastic; torsion; torsional strength.**

test, ultrasonic See **test, nondestructive ultrasonic.**

test, unstable specimen See **metastable.**

test and verification See **design verification.**

test, water-absorption A test that measures the amount of water absorbed by a material under specific test conditions, such as 24 h in water, commonly expressed as weight percent of the material's dry weight. Usually an increase in mass (volume) also occurs. See **absorption; adsorption; test, reinforced-plastic moisture content; water absorption.**

test, water-vapor transmission rate (WVTR) An important test particularly for food packaging. The test can be used with film and sheet and uses a modulated infrared sensor, under ASTM F-1249 procedures. Results are reported in g/m^2/day for testing performed at 37.8°C (100°F) and 100% relative humidity. See **barrier plastic; packaging, food; test, permeability; water-vapor transmission.**

test, weatherability See **aging, artificial; weatherability.**

test, white-box and black-box White-box testing methods are used when the tester must verify the internal workings of the product software to test it adequately. Most manual methods present the product to the tester as a black-box. Testers enter user-level inputs and evaluate the product response. What occurs in between, inside the black-box, is inferred from the results. Such references can be mistaken and therefore dangerous. With white-box testing, the tester is able to look inside the product and create tests to find weaknesses in the program's internal logic. It enables the tester to examine communications protocols, evaluate data structures, analyze timings, and perform other tests that cannot be done any other way. See **black box; coefficient of scatter; communication protocol; computer software; program.**

testing and classification The physical, mechanical, and chemical properties of plastics are governed by their molecular weight, molecular weight distribution, molecular structure, and other molecular parameters; also the nonplastic additives, fillers, and reinforcements that enhance certain processing and/or performance characteristics. Properties are also affected by their previous history, since the transformation of plastic materials into products is through the application of heat (different forms) and pressure involving many different fabricating processes. Thus, definite variations in properties of products can occur even with the same plastic and processing equipment. See **additive; fabricating process type; filler; heat; molecular-weight distribution; plastic material selection; reinforcement.**

testing and people People are involved in testing from raw materials to the end of the fabricating line and need proper training and experience. New problems that appear online may require the development of new tests. New tests may be unnecessarily complex.

testing and quality control (QC) The inspection of components and parts as they complete different phases of processing. Parts that are within specifications proceed, while others are either repaired or scrapped. The workers who made the out-of-spec parts may be notified so they can correct their mistake. This after-the-fact approach to QC identifies defects that are already present in the part being processed but does little to correct the basic problems in production. It constitutes one of the least cost-effective ways of obtaining a high-quality part. Quality must be built into a product from the beginning, such as by following the FALLO approach; it cannot be inspected into the process. The target is to control quality before a part becomes defective. See **FALLO approach; ISO-9000 certification; quality control.**

tetrafluoroethylene (TFE) A flammable, colorless, heavy gas that is insoluble in water and boils at 78°C (172°F). It is used as a monomer to manufacture polytetrafluoroethylene plastic. Also called *perfluoroethylene.* See **polytetrafluoroethylene plastic.**

tex A unit for expressing linear density that is equal to the mass of weight in grams of 1,000 m of fiber, filament, yarn, or other textile strand. See **fiber denier; yarn count.**

textile A general term for fibers, yarns, fabrics, and products that are made from fabrics and that retain approximately the strength, flexibility, and other properties of the original fibers. See **fabric, nonwoven; fabric, woven; fiber.**

textile cone In textiles, a package of yarn wound in transverse form on a conical shaped tube or bobbin. It is unwound from the small end of the package. It is used in filament winding, high-speed wrapping, knitting, and fabric weaving. See **fabric; filament winding.**

textile warp See **yarn warp.**

texture The surface appearance or structure of a solid or semisolid (flexible, elastomeric) material.

texturizing The etching (usually with chemicals or with the controlled corrosion method) or cutting of a pattern on a mold-cavity surface to be reproduced on the molded part. Tool texturing was initially used as a method to minimize the effect of flow lines, sink marks, and other flaws or functional needs on parts and soon became an integral part of the fabricated part design. Plaques are used to identify the different available surfaces. Tooling issues are numerous, such as steel type and hardness, surface finish requirements, metal removal for specified patterns, and mold-cavity design. Because the process incorporates many hand-applied techniques, access to the surfaces that are to be decorated is crucial, and areas with restricted access should also be discussed in the mold design stage. Adjustment of the cavity dimensions may be necessary to compensate for the metal removal that occurs during the etching procedure. Knife-edge inserts and cams are of particular concern.

The decorating options that are available are numerous and elaborate. For example, microtexturing uses a mechanical abrasion process, commonly referred to as *sand blasting*, in which usually glass or aluminum oxide are impacted against the surface of the tool, leaving a lightly scarred steel surface. The appearances that are available are limited to matte textures and some stripes. However, their real value is the ability to reduce gloss levels. Graphic designs such as company logos and written or pictorial information may be etched into tooling surfaces where mechanical means may not be suitable. See **decorating; embossing; film decorating; fiberglass texturizing; in-mold operation; mold cavity, etched; photoetching tool; sand blast.**

T_g See **glass transition temperature.**

T_m See **melt temperature.**

theorem See **mathematical theorem.**

theoretical versus actual properties See **plastics, theoretical versus actual values of.**

theory A unifying principle that explains a body of facts and the laws that are based on those facts. See **atomic theory; design; design-failure theory; design theory and strength of material; empirical; engineering approach versus practical approach; mathematical theorem; mixing theory.**

theory, polymer See **Staudinger, Hermann.**

therimage A decorating process for plastics that transfers the image of a decorated label to the part under the influence of heat and light pressure. See **decorating; label.**

thermal Referring to the use of heat in any heating or curing process and environment.

thermal aging, relative thermal index The UL 746 test provides a basis for selecting high-temperature plastics and provides a long-term relative thermal-aging index. See **Underwriters' Laboratory.**

thermal agitation The thermally induced movement of atoms and molecules.

thermal analysis (TA) Any analysis of physical or thermodynamic properties of materials in which heat is directly involved, with the heat either being added or removed. Different methods are used with each method providing certain useful data or information. See **chemistry, analytical; chromatography, gel; dielectric analysis; differential gravimetric analysis; differential scanning calorimeter; differential thermal analysis; dilatometer; dynamic mechanical measurement; heat capacity; thermodynamic properties; thermogravimetric analysis; thermomechanical analysis.**

thermal analysis, enthalpimetric A method of measuring the thermal energy that is released during a controlled reaction of the specimen. Titrimetric and colorimetric modes are used to test the temperature change in a system while the titrant is gradually added.

thermal capacity The amount of thermal energy that can be stored in a storage device during a period of time and for a specific set of values—that is, the initial temperature of the storage device, the temperature of the entering fluid, and the mass flow rate of a fluid through the storage system. See **aerogel; coolant; insulation resistance.**

thermal characteristic See **orientation thermal characteristic.**

thermal coefficient See **coefficient of thermal conductivity.**

thermal conductance Time rate of heat flow through a unit of a body induced by a unit temperature difference between two body surfaces.

thermal conductivity (TC) The ability of a material to conduct heat. TC is the rate at which a material will conduct heat energy along its length and through its thickness. Generally, plastics have low TC. Different types of plastics provide different degrees in conducting heat. The physical constant for the quantity of heat that passes through a unit of a substance in a unit of time when the difference in temperature of two faces is 1°C. It has an important effect on heating and cooling the plastic melt during processing since it tends to be an insulator. This condition requires special understanding and operating equipment to maximize heating and cooling efficiencies. The TC of plastics depends on several variables and cannot be reported as a single factor. But it is possible to ascertain the two principal dependencies of temperature and molecular orientation. In fact, MO may vary within a product, producing a variation in thermal conductivity. It is important for the product designer and processor to recognize such a situation. Certain products require skill to estimate a part's performance under steady-state heat flow. See **coefficient of thermal conductivity; conduction, heat;**

melt density; orientation; thermal property; thermodynamic phase transformation.

thermal contraction See **coefficient of linear thermal expansion.**

thermal data Information about temperature that is important to material performance during processing, including specific heat with enthalpy curves, heat and temperature conductivity, heat transfer coefficient, pressure-volume-temperature curves, compressibility, specific volume, and coefficient of thermal expansion. See **coefficient of linear thermal expansion; compressibility; enthalpy; heat transfer; temperature properties of plastics; thermodynamic properties; volume, specific.**

thermal decomposition The effect of external application or internal generation of heat on the properties of a material. Also called *degradation*. See **decomposition; degradation.**

thermal diffusivity A measure of the rate at which energy is transmitted through a given plastic. It relates directly to processability. It determines a plastic rate of energy change with time. This function depends on thermal conductivity or specific heat at a constant pressure and density, all of which vary with temperature; nevertheless, thermal diffusivity is relatively constant. Metals have values that are hundreds of times larger than those of plastics. See **energy; fabricating processing; heat transfer; thermal property; thermodynamic properties.**

thermal endurance The time that is required at a selected temperature for a material or system of materials to deteriorate to some predetermined level of mechanical, electrical, chemical, or other performance under prescribed test conditions. See **endurance.**

thermal energy See **ablation.**

thermal expansion See **coefficient of linear thermal expansion; designing with thermal situation.**

thermal expansion/contraction measurement See **dilatometer.**

thermal expansion molding See **autoclave thermal expansion molding; molding, thermal expansion.**

thermal fluid See **heat-transfer fluid.**

thermal inversion See **tensile thermal inversion.**

thermal oxidation See **recycling steel with vinyl scrap.**

thermal property Plastics need to maintain acceptable mechanical and other performance requirements in both the normal and extreme operating environments to which a product will be subjected, including the environment (conditions) during processing to fabricate the product. Processes are influenced by factors, such as the thermal characteristics of plastics, including melt temperature (T_m), glass transition temperature (T_g), thermal conductivity, thermal diffusivity, heat capacity, coefficient of linear thermal expansion, and decomposition temperature (T_d). All these properties relate to the selection of the optimum processing conditions. There is a maximum processing temperature, or to be more precise a maximum time-to-temperature ratio, for all plastics before they initiate decomposition or complete destruction. Thermal properties also change according to the types of additives in plastics. See **glass transition temperature; melt temperature; thermal conductivity; thermal diffusivity.**

thermal radiation See **radiation blackbody.**

thermal reclamation This action goes waste-to-energy. See **energy reclamation; recycling, thermal reclamation.**

thermal resistance Under steady-state conditions, the temperature difference that is required to produce a unit of heat flux through a specimen.

thermal resistivity The reciprocal of thermal conductivity. See **thermal conductivity.**

thermal sealing See **sealing, heat.**

thermal shrinkage See **coefficient of linear thermal expansion.**

thermal spectrometry See **differential thermal analysis.**

thermal spray coating Spraying finely divided metallic and nonmetallic materials in a molten or semimolten condition to form coatings on all kinds of substrates. See **spray coating, thermal.**

thermal stability The resistance to permanent changes in properties that is caused solely by heat. It is occasionally observed that increasing molecular weight produces increased thermal stability, which in turn gives the processor increased latitude during fabrication. See **molecular weight; phosphorous-base flame retardant.**

thermal transference The steady-state heat flow from or to a body through applied thermal insulation and to or from the external surroundings by conduction, convection, and radiation. It is expressed as the time rate of heat flow per unit area of the body per unit temperature difference between the body surface and the external surroundings.

thermister (TM) A semiconductor device with a high resistance dependence on temperature. It may be calibrated as a thermometer. The semiconductor sensor exhibits a large change in resistance that is proportional to a small change in temperature. Normally TMs have negative thermal coefficients. Like resistant temperature detectors, they operate on the principle that the electrical resistance of a conductive metal is driven by changes in temperatures. Variations in the conductor's electrical resistance are thus interpreted and quantified as changes in temperature occur. See **parylene plastic; temperature sensor; zero power resistance.**

thermoanalytical method See **differential thermal analysis.**

thermochemistry See **chemistry, thermo-.**

thermocouple (TC) A thermoelectric heat-sensing instrument that is used for measuring temperature in or on equipment such as the plasticator, mold, die, preheater, or melt. The TC depends on the fact that every type of metallic electrical conductor has a characteristic barrier potential. Whenever two different metals are joined together, there will be a net electrical potential at the junction. This potential changes with temperature. See **coefficient, Peltier; constantin; pyrometer; radiation pyrometer; temperature measurement; temperature sensor.**

thermocouple burn-out protection The protection of the heating system thermocouple when its wire is broken.

thermocouple, differential Two thermocouples placed in series position.

thermocouple in barrel See **temperature controller.**

thermodilatometer See **dilatometer.**

thermodynamic phase transformation In thermodynamic equilibrium a system may be composed of one or several physically distinct macroscopic homogeneous parts called *phases*, which are separated from one another by well-defined interfaces. These phases are determined by several parameters, such as temperature, pressure, and electric and magnetic fields. By continuously varying the parameters it is possible to induce the transformation of the system from one phase to another. See **Reynold's number; thermal conductivity.**

thermodynamic postulations See **temperature, absolute zero.**

thermodynamic properties Heat exchange occurs during heat processing. The heat content of the melts (about 100 cal/g) together with the low rate of thermal diffusion (10^{-3} cm^2/s) limits the cycle time of many processes. Also important are density changes, which for crystalline plastics may exceed 25% as melts cool. Melts are highly compressible; a 10% volume change for 10,000 psi (69 MPa) force is typical. Surface tension of about 20 g/cm may be typical for film and fiber processing when there is a large surface-to-volume ratio. Thermodynamic properties provide a means of working out the flow of energy from one system to another. Any substance of specified chemical composition perpetually in electrical, magnetic, and gravitational fields, has five fundamental thermodynamic properties—namely, pressure, temperature, volume, internal energy, and entropy. All changes in these properties must fulfill the requirements of the first and second laws of thermodynamics. The third law provides a reference point, absolute zero temperature, for all these properties, although such a reference state is unattainable. The proper modes of applying these laws to the above five fundamental properties of an isolated system constitute the well-established subject of thermodynamics. See **energy, law of conservation; energy, plastic work; enthalpy; entropy; mold heat-transfer device; pressure; temperature; thermal analysis; thermal diffusivity; thermometer; volume.**

thermodynamics The scientific principle that deals with the interconversion of heat and other forms of energy. Thermodynamics (*thermo* = "heat" and *dynamic* = "changes") is the study of these energy transfers. The law of conservation of energy is called the first law of thermodynamics. See **chemistry, thermo-; energy, law of conservation of; heat capacity; melt density; temperature, absolute zero; thermal conductivity.**

thermodynamics, first law of Energy can be converted from one form to another, but it cannot be created or destroyed.

thermodynamics, second law of The entropy of the universe increases in a spontaneous process and remains unchanged in a reversible process. It can never decrease. See **entropy.**

thermodynamics, statistical This discipline tries to compute macroscopic properties of materials from more basic structures of matter. These properties are not necessarily static properties as in conventional mechanics. The problems in statistical thermodynamics fall into two categories. The first category involves the study of the structure of phenomenological frameworks and the interrelations among observable macroscopic quantities. The secondary category involves the calculations of the actual values of phenomenology parameters, such as viscosity or phase transition temperatures from more microscopic parameters. With this technique, understanding general relations requires only a model specified by fairly broad and abstract conditions. Realistically detailed models are not needed to understand general properties of a class of materials. Understanding more specific relations requires microscopically detailed models. See **mechanical property; statistic.**

thermodynamics, third law of The entropy of a pure perfect crystal is zero at absolute zero temperature.

thermoelastic effect The related effects of temperature (enthalpy) and elasticity of a material. For example, the temperature of an elastomer increases on stretching and decreases on retraction. Also as the temperature of a stretched elastomer is increased, the material contracts, whereas expansion occurs if it is cooled; the linear coefficient of expansion is negative at low elongation, where the property of thermoplastic inversion is said to occur. See **elasticity; enthalpy.**

thermoelastic inversion See **tensile thermoelastic inversion.**

thermoelasticity The rubberlike elasticity that is exhibited by a rigid plastic and results from an increase of temperature.

thermoflow plastic In 1994 researchers at Akzo Nobel in Arnhem, The Netherlands, reported that a new plastic was functioning like a thermoset plastic at low temperatures of 150°C (302°F) or lower but like a thermoplastic at higher temperatures. The material is a covalent, cross-linked plastic. Its chemical structure disassociates into a low-volatile oligomer when heated and returns to the cross-linked network when cooled. It has a very low viscosity of −3.0 Pa at 190°C (374°F). It is targeted for applications such as encapsulation, impregnation of porous material, adhesive, and laminate. See **plastic and the future; research and development.**

thermoforming Thermoformed (3-dimensional shape) plastics provide a great variety of marketable products in sizes that range from drinking cups to pick-up truck storage wells. The process of thermoforming is considered one of the four major fabricating processes, following extrusion, injection molding, and blow molding. Since the plastic sheets and films used in thermoforming are extruded, the name *extrusion thermoforming* is sometimes used. About 30wt% percent of all extruded products are thermoformed. They have many advantages over other manufacturing methods. For the mass production of products (packaging, picnic dishes, etc.) sheets and films can be produced inline with thermoforming equipment. The other major procedure is feeding rolls or flat sheets or films of materials to the thermoforming equipment. Extruding sheet or film inline requires close control to ensure that both the extruder and the thermoformer are operating efficiently. Advantages include cost savings. The thermoforming process heats the sheet to the point at which it is soft and flowable and then applies differential pressure to make the sheet conform to the shape of the mold or die positioned below the frame. The use of the terms *thermoforming* or *forming* in the plastics industry does not include such operations as molding, casting, or extrusion, in which shapes or parts are "formed." Some inline systems form film or sheet products, such as food packaging containers. See **automobile, composite; elastic memory; environment and public opinion; forming; forming, stretch and draw ratios for pressure; orientation; postforming; thermoplastic.**

thermoforming, air-assist Air flow and air pressure are used to preform a heated sheet prior to the final pull-down onto the mold using vacuum between the heated sheet and mold cavity.

thermoforming, air-slip A variation of snap-back thermoforming in which the mold is enclosed in a box, such that when the mold moves forward toward the hot plastic, air is trapped between the mold and the sheet. On the full travel of the sheet, a vacuum is applied to remove the air, providing the sheet with a very snug fit over the mold. See **thermoforming, drape with bubble stretching.**

thermoforming, billow Heated sheet is clamped over a billow chamber. Air pressure in the chamber is increased, causing the sheet to billow against a descending male mold. See **packaging, blister.**

thermoforming, blister-package Thin plastic film is thermoformed into simple to very complex shapes for packaging different products, such candy, fruit, or toys. Certain products can be used as molds. See **orientation, shrink-film; packaging, contour; thermoforming, shrink wrapping.**

thermoforming, blowing A method of shaping thermoplastic sheets such as PMMA and CA using compressed air. Process consists of securing the edges of a heated sheet to a metal backing plate and applying about 15 psi (100 kPa) internal pressure to blow to a desired shape such as bubble canopies or aircraft blisters.

thermoforming, blow molding, stretched See **blow molding, stretched-operation specialty.**

thermoforming, bubble Sheet is clamped into a frame suspended above a mold, heated, blown into a blister shape by air, then molded to shape by means of a descending male plug applied to the blister, forcing it downward into the mold.

thermoforming, clamshell A variation of blow molding and thermoforming in which two preheated sheets are clamped between two halves of a split mold (like a two-part mold used to form the final blow molded part). Each sheet is drawn into their individual mold cavities by vacuum as air is simultaneously injected between the sheets. An end contact could include an integral hinge. See **molding, two-shell.**

thermoforming coextruded film or sheet The performance advantages of coextrusion can be applied to thermoforming. See **coextrusion.**

thermoforming, cold forming A technique for forming thermoplastic sheets at room temperature. Also called *cold drawing*. See **forming, cold.**

thermoforming, comoform cold forming/molding An extension of the cold-molding (como) process that utilizes a thermoformed plastic skin to impart excellent surface and other characteristics to a cold-molded reinforced plastic or laminated cured material. See **molding, cold.**

thermoforming, drape A method in which the sheet is clamped into a movable frame, heated, and draped over high points of a male mold. Vacuum is pulled to complete the forming operation.

thermoforming, drape with bubble stretching A modified system of drape forming that produces a more uniform wall thickness and minimizes the dangers of tearing over the corners of large moldings because of the protective cushion of compressed air above the rising mold. The film or sheet is heated and blown into a "bubble" so that the sheet is prestretched before forming. See **thermoforming, air-slip.**

thermoforming draw To stretch a sheet to fit a mold and conform to the mold's cavity shape. See **draw.**

thermoforming extruder line The heated sheet or film goes directly through a continuous operating thermoforming machine. Also called *extrude melt-to-mold process*. See **extruder thermoforming line; postforming.**

thermoforming flat shape See **oil canning.**

thermoforming, form and spray Sheet is thermoformed into a product. To reinforce it, the back surface receives a spray-up of reinforced plastic. See **reinforced plastic, spray-up.**

thermoforming, form, fill, and seal (FFS) FFS pouches are extensively used in packaging. They are thermoformed online with contents automatically inserted in the pouch just prior to the sealing action. Sheets or films are formed using a clam-shaping procedure using two sheets or a single sheet that is shaped and sealed where the two edges meet to form the pouch just prior to filling. Online zippers may be sealed to the pouches or bags. See

blow molding, extruder blow, fill, and seal; extruder-blown film-bag manufacturing; medical packaging; sealing.

thermoforming heater Heaters are evaluated based on initial cost, operating cost, energy efficiency, durability, profile control capability, and how the cycle time is affected. Most heaters are considered throwaway. Some heaters can be repaired, but their designs typically shorten the heating element's life. Heaters' average lives, when proper maintenance is used, are as follows: 10,000 h for quartz tubes, 10,000 to 15,000 h for ceramic elements, 15,000 to 25,000 h for calrods, 25,000 for panels, and 10,000 to 12,000 h for gas catalyst. Recognize that cooling time usually slows down cycles more than heating. See **heater; thermoforming, temperature control.**

thermoforming heater, calrod See **thermoforming heater, metal-sheathed.**

thermoforming heater, catalytic gas These systems are the newest heating options and tend to be controversial. They have lower operating cost (50 to 80% energy saving) but a higher purchase price. The heater is a stainless steel panel containing a perforated steel plate to distribute the gas over a ceramic-fiber mat that is impregnated with a platinum catalyst. The catalyst converts propane or natural gas into carbon dioxide and water without generating a flame. A metal-sheathed tubular electric heater is used to preheat the panel to 120°C (250°F), the threshold at which the catalytic conversion begins. Safety devices are used to ensure proper operation. Heater control uses gas pressure as a reference rather than the heater temperature. Since they operate at a lower watt density and temperature than electric heaters, they cannot be used with materials that require forming temperatures above 260°C (500°F).

thermoforming heater, ceramic A flat or concave (with reflectors) heater in which the element focuses the energy rather than emitting parallel rays like a flat heater. Flat panels do not require a reflector and can be placed closer to each other and to the sheet. About 98% of the emitted energy is infrared. Ceramic heaters are fairly rugged (they can be used in the bottom of the oven) and cost slightly more than metal-sheathed tubular elements. Replacing a tubular with a ceramic of the same watt density will save energy because it holds heat longer. The drawback is that their many separate elements could leave about 35% of the space in an oven with open gaps that can cause striping if the sheet is too close. See **ceramic.**

thermoforming heater, electric panel The panel radiates heat across its entire surface, providing uniform heat over a broader area than is provided by separate smaller heaters. Both striping and no-heat zones between elements are less of a concern with panel heaters. Emitters give off 80 to 90% of their energy as useful heat.

thermoforming heater, halogen These heaters are reported to have the fastest heat-up of all heaters (as little as 0.2 s) and emit most of their energy at a wavelength of 1 micron at their maximum temperature of 1100°C (2,000°F). They provide energy savings of 18 to 20% compared to quartz-tube heaters. They heat only the sheet, not the ambient air. The complete machine that includes the molds remains cool enough to touch. Risk of fire is lower because of no ambient heat. Sheet heats faster and cools faster. Finer temperature control exists than with most quartz heaters. See **halogen.**

thermoforming heater, metal-sheathed These tubular heating elements are the inexpensive workhorse of the industry and are commonly known as *calrod.* They have a relatively fast heat-up time (1.5 min), quick response to setpoint changes, and take a lot of abuse. However, they radiate in every direction, resulting in low efficiency. Reflectors redirect the infrared and if kept clean can be helpful. Open-loop heat controls are used.

thermoforming heater, tubular quartz These heaters have a helical resistance wire within a quartz tube and use a reflector to concentrate the heat on the plastic sheet. Their greatest asset is quick heat-up and cool-down ability permitting complete shut-off between the heating cycles saving energy. Control is by open-loop. They are about 60% efficient when new, with a slight drop-off after use. They are fragile and are not appropriate for bottom heating.

thermoforming machine A machine that uses precut sheets that are manually or automatically fed to the machine or continuous sheets that are fed from a roll or directly from an extruder into a continuous operating thermoforming machine. Tight synchronization is required to avoid constant downtime. Machines can range from home-made or equipment manufacturer of simple single-stage operation thermoformer to sophisticated multistage computerized machines.

thermoforming material Various thermoplastics are used in thermoforming, but thermoset plastics (B-stage) can be used. Uniformity in thickness of the sheet or film is very important to ensure good repeatability in duplicating precision products. Even with products not requiring good repeatability, cost advantages can occur with the tighter-tolerance material. The quality of sheets varies depending on whether they are purchased on the basis of weight or length; purchasing by weight with a wide tolerance results in a shorter length. See **A-B-C stages; thermoforming thermoset plastic; thermoplastic; thermoset plastic; tolerance.**

thermoforming, melt-to-mold See **thermoforming extruder line.**

thermoforming mold Tools (molds) for forming are of all sizes and shapes. For production runs, they generally are made from cast or machined aluminum that include many vent holes of approximately 0.001 to 0.002 in. (0.003 to 0.005 cm) in width to allow for air movement from between the heated sheet and the mold-cavity surface. Back drilling of larger holes on the underside can be used to aid in the vacuum action. Narrow slots also can be used since they offer much less resistance than holes when air is evacuated through the mold. Also used is porous or sintered metal, which provides exceptional air-removal capability. These vents are small enough that no surface imperfections occurs. Other materials of construction include wood, reinforced plastic, steel, and kirksite. The material used depends on the heat transfer desired (heating the mold to develop improved surface finish and cycle time), part quantity, availability, and cost. See **automobile, composite; electroforming; mold; mold cavity; mold material, sprayed-metal; mold, porous; photoetching tool; plate-out; porous metal; vent hole; venting.**

thermoforming package See **packaging, blister; packaging, contour.**

thermoforming, plug A process in which a plug or male mold is used to partially preform the heated part before forming is complete using vacuum or pressure. See **thermoforming, unequal stretch.**

thermoforming, plug and ring A plug functioning as a male mold is forced into a heated plastic sheet held in place by a clamping ring.

thermoforming, pneumatic control With a vacuum system a sheet is subjected to the required heat for softening and forced against a mold cavity. The hot, pliable material is moved rapidly to the mold (for example, by gear drives) or is moved by an air-pressure differential that holds it in place as it cools. When the proper cooling set temperature is reached, the formed part can be removed from the machine manually or automatically, depending on the machine capability. The two important requirements that are met during this cycle are to maintain uniform temperature and sustain pressure on the sheet. Generally, the faster a vacuum is created, the higher the part quality. The desired situation is to use a mold where some heat can be applied; with proper heat the fast vacuum will produce a part with no or relatively little internal stress. During forming the vacuum gauge should never fall below 20 in. of mercury (Hg), which at sea level is 9.82 psi of atmospheric pressure on the part. For proper pressure regulation, a vacuum storage or surge tank is necessary to retain the minimum even vacuum. For long forming cycles, a surge tank will permit the use of a smaller vacuum pump than would otherwise be required. It is sometimes necessary to prestretch (or preblow) the hot sheet before final forming. Usually 3 to 5 psi compressed air is used, which results in a greater amount of air being at atmospheric pressure than in the processing of nonstretched parts. See **pressure, absolute; stress, residual.**

thermoforming, prebillow Prestretching of the heated plastic sheet by differential air pressure is used prior to thermoforming the part; it provides for ease in forming the more complicated shapes.

thermoforming, preprinting Printing of a distorted pattern on a plastic sheet that is then thermoformed to the desired shape, bringing the printed pattern into the proper undistorted shape. See **cut, kerf, and registration; printing.**

thermoforming, pressure A process in which pressure is used to push a heated sheet to be formed against the mold surface as opposed to using a vacuum to suck the sheet against the mold-cavity surface. A combination of pressure and vacuum is usually used, particularly with complex shapes, to ensure removal of entrapped air between the sheet and mold. See **forming, stretch and draw ratios for pressure; forming, scrapless.**

thermoforming, prestretched Stretching or orienting the heated sheet (at orientation temperature) prior to forming into a shape to take advantage of improved performance of the orienting operation. See **orientation.**

thermoforming, rigidizing See **thermoforming, form and spray.**

thermoforming sag The condition when the sheet to be thermoformed is heated and droops intentionally. If it is unintentional, then it is usually referred to as *sagging*.

thermoforming, sandwich heating For typical conventional electric heaters, the sheet is heated from both sides simultaneously prior to forming to ensure fast and uniform heating of the sheet from its surface to surface. See **thermoforming heater.**

thermoforming, scrapless See **forming, scrapless.**

thermoforming shrink fixture See **shrinkage block jig.**

thermoforming, shrink-wrapping A technique of packaging in which the strains in a plastic film are released by raising the temperature of the film, thus causing it to shrink over the package where the package acts as a mold. These shrink characteristics are built into the film during its manufacture by stretching it under controlled temperatures to produce orientation of the molecules. On cooling, the film retains its stretched condition but reverts toward its original dimensions when it is heated around the package. Shrink film gives good protection and excellent clarity. See **orientation, shrink-film; packaging, contour, thermoforming, blister package.**

thermoforming, slip Sheet material is allowed to slip through mechanically operated clamping rings during stretch-forming to produce the desired final shape of the part. See **forming, slip.**

thermoforming, snap-back Forming technique in which an extended heated plastic sheet is allowed to contract over a male form shaped to the desired contours.

thermoforming, solid-phase pressure A technique that forms a solid thermoplastic. A plastic blank is heated and fabricated (forged) by bulk deformation in a forced (pressure applied) constraining die/mold (metal male plug that matches a female metal cavity). The process is used with crystalline plastics; they can be permanently deformed at temperatures below their glass transition temperature (T_g) and melting point (T_m). Amorphous plastics are generally too stiff to be rapidly formed into stable products. Also called *solid-state stamping*. See **amorphous plastic; blank; crystalline plastic; forming, solid-phase pressure; glass transition temperature; melt temperature.**

thermoforming, stretch A technique that stretches heated sheet over a male mold and then draws it to the mold form by vacuum or pressure. See **orientation.**

thermoforming, superplastic The superplastic forming (SPF) process is a strain rate sensitive forming process that uses characteristics of materials exhibiting high elongation to failure. See **elongation; strain rate.**

thermoforming, temperature control Forming requires thorough, fast, and uniform radiant heat from the surface to the core to the surface. As a general guide, to achieve these conditions, sheet plastics over 0.040 in. (1.02 mm) should use sandwich-type (under and over the sheet) heater banks. To ensure that sufficient heat is used, heaters should have capacities of at least 4 to 6 kW/sq. ft. Various types of heating elements are used. The cycle time is controlled by the heating and cooling rates, which in turn depend on the following factors: the temperature of the heaters and the cooling medium, the initial temperature of the sheet, the effective heat-transfer coefficient, the sheet thickness, and thermal properties of the sheet. Different plastics absorb radiant heat most efficiently at various wavelengths, which in turn are affected by the temperature of the emitting heater. The proper wavelength must be used to achieve the most efficient performance and energy cost. With an inline operation from an extruder delivering heated sheet to the thermoformer, energy savings from 30 to 40% can occur with reduced floor space. See **temperature controller; thermoforming heater; thermoforming, unequal stretch.**

thermoforming thermoset plastic Practically all thermoforming material used are thermoplastics, but thermoset plastics can be thermoformed. Commercial roll-fed thermoforming machines form TS polyimide film (for electrical parts) at temperatures as high as 540°C (1,000°F). Prior to being roll-fed, they are sheet-fed. Other TS plastics formed include CPET and reinforced TS polyester plastics. All are formed above their glass transition temperatures. Specialty products, such as TS polyester-glass fiber reinforced plastics, have been made into boat hulls. See **reinforced-plastic prepreg; thermoforming material; thermoset plastic.**

thermoforming, thermotropic liquid crystal in A liquid crystalline polymer that can be processed using thermoforming techniques. See **liquid crystal polymer or plastic; thermotropic.**

thermoforming, trimming Unless a scrapless forming process is used, thermoformed parts require trimming. Various cutters are used, depending on shape of part and plastic used. See **cutting.**

thermoforming, twin-sheet See **thermoforming, clamshell.**

thermoforming, unequal stretch With constant suction created by the vacuum across the sheet, the major portion of the sheet is pulled down until it contacts the female mold cavity. But the sheeting at the edges of the mold or close to the clamp is stretched most and thus becomes the thinnest portion of the formed part. If this situation is not desired, a number of methods are used that partially correct this situation. One approach is vacuum forming into a female mold with a helper (plug-assist). The shaped plug is roughly the shape of the formed part. It pushes the heated sheet into the cavity, stretching it to the plug shape prior to the vacuum action. The amount of stretch can be controlled by means of the plug's variable temperature. Thus, the sheet is deformed in its central portion prior to the vacuum action pulling at the edges. The result is a more uniform wall thickness and allows a deeper depth-to-diameter ratio. Possible drawbacks are that the plug may leave some surface marks and the clarity or gloss may be reduced. With a male mold there is less thinning on the edges because the mold acts like the plug-assist device. See **thermoforming, plug; thermoforming, temperature control.**

thermoforming, vacuum A method of sheet thermoforming in which the plastic sheet or film is clamped into a stationary frame, heated, drawn down by vacuum into a mold, and cooled, producing a predetermined-shape part that allows for cooling shrinkage. Also called *drape forming* or *sheet-forming techniques.*

thermoforming versus injection molding Thermoforming can offer certain advantages over injection molding. TF requires lower capital equipment investment (particularly lower mold cost), shorter mold delivery times, and less maintenance. Rather large parts can be formed. Parts with different thicknesses can usually be formed on the same mold with only minor heating and cooling cycle changes. Fewer stresses can occur with no weld lines. Many parts that are IM cannot be TF; the most common competition is in producing products such as drinking cups where both sides have advantages and disadvantages. The major advantage with IM is providing parts that meet tighter tolerances and quality control as well as a multitude of shapes impossible with TF. Over ten times more plastic is IM than TF. See **plastic consumption.**

thermoforming, web and bridge The undesirable excess fold that may occur, particularly with drape forming. The plastic not being able to shrink as rapidly as it is being forced to conform to a shape of the mold by differential pressure.

thermoform A product that has been thermoformed.

thermogram See **differential thermal analysis.**

thermographic transfer process See **printing, thermographic transfer.**

thermography, infrared See **injection-molding infrared temperature control.**

thermogravimetric analysis (TGA) A chemical analysis by the measurement of weight changes of a system or compound as a function of increasing temperature with time. Properties measured include thermal decomposition temperature, relative thermal stability, chemical composition, and the effectiveness of flame retardants. See **chemical analysis; kinetic; thermal analysis.**

thermogravimetric analysis, vacuum thermobalance An instrument consisting of a precision balance and furnace that have been adapted for continuous measuring and recording changes in weight of a substance as a function of temperature.

thermomechanical analysis (TMA) A test that measures the dimensional changes as a function of temperature. The dimensional behavior of a material can be determined precisely and rapidly with small samples in any form, such as pellet, film, powder, fiber, and molded part. Measurements made include coefficient of linear thermal expansion, glass transition temperature, softening characteristic, modulus, deflection temperature under load, and degree of cure. Samples can be evaluated that are taken from failure sections of parts. It also provides a fast means to evaluate incoming materials. See **coefficient of linear thermal expansion; glass transition temperature; temperature, softening range; thermal analysis.**

thermomechanical spectrum A plot of any mechanical property against temperature. If the temperature range includes the transition zone of viscoelastic behavior, then the term *viscoelastic spectrum* can be used. See **viscoelasticity.**

thermometer An instrument for measuring temperature. There are different types: (1) gas, in which either the pressure is at constant volume or the volume is at constant pressure, measures for extremely accurate thermodynamic determinations; (2) bimetallic sensing elements provide a range of −185 to 425°C (−300 to 800°F); (3) thermoelectric or thermocouple measures by the electromotive force generated by two dissimilar metals providing a range of −200 to 1,800°C (−328 to 3,270°F); (4) the resistance type measures temperature by change in the electrical resistance of a metal, usually platinum, providing a range from −163 to 660°C (−260 to 1,220°F); (5) the optical fiber type has a very accurate range up to 2,000°C (3,632°F). See **temperature measurement; temperature sensor; thermodynamic properties.**

thermometer, partial-immersion An instrument that indicates temperature correctly when the bulb and a specific part of the stem are exposed to the temperature being measured. The remainder of the stem containing the liquid index will be exposed to temperatures that may or may not be different. For measurements of greatest accuracy, the temperatures of the exposed portion should be specified.

thermonuclear reaction A nuclear fusion reaction that occurs at very high temperatures.

thermoplastic (TP) A plastic that after processing via heat and cooling into parts is capable of being repeatedly softened by reheating. See **commodity plastic; engineering plastic; recycling; residence time; rubber, synthetic; test, melt-index; thermoflow plastic; thermoset plastic.**

thermoplastic, cross-linking Certain TPs, such as polyethylene plastics, can be converted to thermoset plastics by chemical cross-linking. See **cross-link.**

thermoplastic elastomer (TPE) A plastic or plastic blend that resembles vulcanized rubbers in that they can be deformed significantly at room temperature, such as twice their original length, and return to their original shape after the stress is removed. TPEs exhibit widely different properties. For example, there are low-durometer, low-modulus TPEs. They include styrenic block copolymers, polyolefin blends, and elastomeric alloys. Soft TPEs are used in ergonomic product designs incorporating soft-touch elements. They compete with thermoset rubbers. Also called *thermoplastic rubber, TPEL,* or *TPV.* See **elastomer; design energy and motion control; rubber; thermoset elastomer; vulcanized elastomer.**

thermoplastic elastomer polyolefin (TPE-O) TPE-Os are polyolefins from cross-linked EPM or EPDM, but also simple blends of EPM or EPDM with PP or PE. The TPE-O's properties depend critically on the particle size of the rubber. Also called *thermoplastic olefin* (TPO), *compounded TPO* (CTPO), and *reactor-made TPO* (RTPO). See **polyolefin.**

thermoplasticity The ability of a material to be deformed without breaking. See **plasticity.**

thermoplastic reinforced sheet stamping See **stamping reinforced thermoplastic.**

thermoplastic-thermoset plastic See **thermoflow plastic.**

thermoplastic vulcanizate (TPV) A specific type of thermoplastic elastomer that is made by alloying a TP with rubber, which is partially or fully vulcanized during the alloying process. Examples are PP and EPDM. These hygroscopic materials have been successful in extrusion blow molding, replacing thermoset rubber parts. Processing TPVs offers the following advantages when compared to thermoset rubbers: they are fully formulated without added compounding, can be black or colored, have faster cycle times, are recyclable, have tighter part tolerances and lower density parts, and are more efficient and cost effective. See **elastomer; extruder; plastic, hygroscopic; vulcanizate.**

thermoset elastomer (TE) A thermoset material that provides the characteristic of an elastomer, such as natural rubber. See **elastomer; rubber; thermoplastic elastomer.**

thermoset plastic (TS) A plastic that, after final processing into products, is substantially infusible and insoluble. TSs undergo a chemical reaction (cross-linking) by the action of heat and pressure, oxidation, radiation, or other means, often in the presence of curing agents and catalysts. Curing occurs via polymerization or cross-linking. Cured TSs cannot be resoftened by heat. However, they can be granulated and used as filler in TSs as well as TPs. Also called *thermoset resin, thermosetting resin,* or *thermoset elastomer.* See **A-B-C stages; cross-link; dielectric monitoring; exotherm; gel point; infusible; resinoid; resitol; rubber, synthetic; screw, thermoset type; temperature and molecular bonding force; vulcanization, de-.**

thermoset plastic binder/matrix Thermoset binders are a constituent part of a very large group of engineering products.

thermoset plastic cured-in-place pipe See **sewer rehabilitation.**

thermoset plastic curing See **welding, induction.**

thermoset plastic curing, dielectric monitoring Monitoring the cure of a thermoset plastic, which can be done by tracking the changes in their electrical properties during processing, particularly with reinforced plastics. In a typical application, a sensor is placed at the location where the cure is to be monitored. During cure the capacitance and conductance of the material are recorded; measurements are taken at several frequencies over several orders of magnitude. From these data, the value of the ionic conductivity is deduced. There exists a relationship between the ionic conductivity and the melt viscosity to the degree of cure. See **cure; curing, dielectric; dielectric monitoring; dielectrometry; electrical cure monitoring; reinforced plastic.**

thermoset plastic curing, electromagnetic monitoring A nondestructive insitu electromagnetic-impedance measurement technique. It senses cure-processing properties of high-temperature, high-performance thermoset and thermoplastic materials. Frequency-dependent impedance measurements are particularly important in assuring the quality of the plastic and controlling the curing process.

thermoset plastic curing, fiber-optic sensor With some of the methods used to mold or cure thermoset plastics, the hostility of the environment both within and around a reinforced plastic may preclude the use of conventional-style sensors. The situation can be handled using fiber-optic sensors to monitor the cure. Because of their hair-size, they can remain embedded in the RP parts. They have been extensively used in pultrusion lines. See **fiber optic; reinforced-plastic pultrusion.**

thermoset plastic melt-flow test See **test molding index; test, spiral melt-flow; test, thermoset flow.**

thermoset plastic staging Heating a thermoset premixed compound, such as a prepreg, until the chemical reaction (cure) starts, but stopping the reaction before the gel point is reached (B-stage). Staging is often used to reduce plastic flow. See **A-B-C stages.**

thermoset rubber See **elastomer; vulcanizate.**

thermostamping plastic See **stamping.**

thermotropic A material in which the shape and packing of the macromolecules is affected by temperature. See **thermoforming, thermotropic liquid crystal in.**

thermotropic liquid crystal See **liquid crystal polymer or plastic; thermoforming, thermotropic liquid crystal in.**

thickening agent A material that is added to a plastic to thicken it or raise the viscosity index so that it will not flow as readily. Agents impart thixotropy. Examples include bentonite, calcium carbonates with high oil absorption, hydrated siliceous minerals, magnesium oxide, soap, stearates, and special organic waxes. They are used in molding compounds and coatings. Also called *antisag agent* and *thickener.* See **antistatic agent; plastigel; reinforced-plastic sheet-molding compound; sag; thixotropy.**

thick molding compound See **bulk molding compound.**

thickness gauge A mechanical-caliper, ultrasonic, or magnetic gauge that is used for precise measurement. See **extruder-blown-film gauge distortion.**

thickness gauge, ultrasonic A gauge that calculates part thickness by timing a sound wave emitted from a sensor. For example, the sensor can be located in a mold wall that sends the signal through the material and back and then calculates it against a mechanically measured part sample.

thickness tracer See **radioisotope.**

thinner A liquid solvent that can extend a solution but not reduce the power of the solvent. See **solvent.**

Thixomolding This Thixomat Inc. process includes the high-volume injection molding of semimolten magnesium alloy chips into high precision complex shapes. See **injection-molding nonplastic.**

thixotropy The opposite of rheopecticity. See **rheopecticity.** A characteristic of material undergoing flow deformation, where viscosity increases drastically when the force inducing the flow is removed. The material is gellike at rest but fluid when agitated, such as during molding. It loses viscosity under stress. See **dilantic; melt strength; rheology.** Thixotropes, with their dual rheological behavior, differ from thickeners, with their single rheological behaviors. See **silica; thickening agent.** Liquids containing suspended solids are likely to be thixotropic. They have high static shear strength with low dynamic shear strength at the same time. For example, these materials can be applied on a vertical wall and through quick curing action remain in position during curing. See **reinforced plastic bulk-molding material.**

thread See **fiber.**

thread, buttress A type of thread that is used for transmitting power in only one direction. It has the efficiency of the square thread and the strength of a V-thread.

thread-forming screw A type of self-cutting screw that forms threads by displacing and deforming plastic material, which then flows around the screw head. Because no material is removed, large thermal stresses are produced in the plastic. Stress relieving can take place by applying heat if it is practical. See **annealing.**

thread molding See **molded screw thread.**

thread pitch diameter The average between the major (outside) and minor (root) diameter of a thread. For practical purposes, this diameter is assumed to be equal to the diameter of the smooth shaft prior to threading. See **fiber.**

thread-up See **extruder operation startup.**

thread, V Thread with leading flank of adjacent thread at the thread root.

three-dimensional blow molding See **blow molding, three-dimensional.**

three-roll stack See **extruder sheet.**

through-hole, printed circuit See **printed circuit board.**

throughput See **fabricating output.**

thyristor A transistor that has a triggerlike characteristic. It is used to give high-speed triggering action. See **electric motor; sensor; transistor.**

tie-bar growth See **injection-molding machine tie-bar growth.**
tiebarless molding See **clamping, tiebarless.**
tie layer A material that can provide adhesion between layers, such as coextrusion, coinjection, in-mold decorating, and laminating. These tie layers join dissimilar materials to synergize their respective properties. End products are as diverse as packaging cheese to automotive fuel tanks. See **coextrusion; coinjection molding; in-mold decorating; laminate.**
tie rod See **clamping tie bar.**
tile See **vinyl composition tile.**
time See **measurement.**
time, constant The time required for the output to complete 63.2% of the total rise as a result of a step change of the input. See **fabricating.**
time, dead The interval of time between initiation of an input change and the start of the resulting response. Also called *transportation lag.*
time, lead The total number of calendar or production (fabrication) days between the time a purchase order or production order is placed until the goods are received or production is complete. Also called *replenishment time.*
time, life-cycle See **aging; life-cycle analysis; plastics cradle-to-grave; plastic long-life; vinyl composition tile.**
time, long life See **plastic long-life.**
time profile The plot of characteristics versus time such as modulus or damping of a material. See **damping; modulus.**
timer An analog or digital device that is used to accurately control processing equipment requiring timing schedules or cycles.
tin coating See **recycling steel with vinyl scrap.**
tint See **color tint.**
tire, camelback See **rubber tire, camelback.**
tire cord fabric, weftless See **weftless.**
titanate coupling agent A substance that permits high filler loadings, significantly reduces viscosity, and can be used with many mineral fillers to improve flow and various mechanical properties. It is widely used in applications with calcium carbonate fillers, where silanes alone are not applicable. These agents serve as molecular bridges between inorganic fillers and organic plastics. The reaction with the free protons at the inorganic interface results in monomolecular layers of organo-functionality joining the organic and inorganic elements together. See **fiberglass binder/sizing coupling agent; reinforced-plastic coupling agent.**
titanium alloy See **mold-cavity coating.**
titanium dioxide (TiO_2) The most important white pigment. It accounts for about 65wt% of the total pigment consumption. It is a nontoxic, white colored inorganic pigment of excellent whitening power. As well as producing white color, it is an essential ingredient in the production of all pastel shades. Produced from a naturally occurring ore, it is suitable for use with all plastics, including being used as a filler. See **colorant; pigment.**
titanium modulus versus specific gravity See **modulus versus specific gravity.**
titration A method of analyzing the composition of a solution by adding known amounts of standardized solutions until a given reaction (color change, precipitation, or conductivity change) is produced. See **redox titration.**
toggle clamping action See **clamping, toggle-action.**
tolerance A specified allowance on deviation in parameters such as dimensions, weights, shapes/angles, and compounding mixtures, at standard or stated environmental conditions. See **accuracy; concentricity; damage tolerance; design clearance; dimensional property; machine quality; mold standard and practice; plastic, low-profile; product size; tolerance, full-indicator-movement.**
tolerance allowance An intentional difference between maximum material limits of mating parts. It is the minimum clearance (positive allowance) or maximum interference (negative allowance) between such parts.
tolerance analysis See **design and tolerance.**
tolerance and shrinkage Two different forms of shrinkage must be considered when designing to meet tolerances: the initial shrinkage that occurs while a part is cooling after fabrication, called the *mold* or *die shrinkage,* and the shrinkage that occurs after as many as 24 hours, called the *after-shrinkage* or *after-swell.* Some plastics are extremely stable, and some others are very close to being stable, so that once cooled, dimensions (and other factors) do not change. However, many plastics shrink without influencing performance of the parts when in service. In many cases low shrinkage may indicate more stability of the plastic part. Large, unpredictable shrinkages can make close tolerance designing with those plastics almost impossible. If a part has to be postcured or annealed to relieve internal stresses, allowance is to be made if the material shrinks during this secondary operation. See **annealing; compounding; design shrinkage; melting temperature; shrinkage.**
tolerance and warpage Warping is usually caused by the shrinkage behavior of plastic that may be a characteristic of the plastic but more probably of the way it was processed. Corrective action can be taken by controlling the fabricating process to eliminate or (if permitted) almost eliminate the warpage, which in turn permits meeting tolerance requirements. See **process control; stress, residual; warpage.**
tolerance, dimensional tight See **zinc.**
tolerance, dimensioning limit See **dimensioning limit.**
tolerance, full-indicator-movement (FIM) A term that is used to identify tolerance with respect to concentricity. Terms used in the past were *full indicator reading* (FIR) and *total indicator reading* (TIR). See **concentricity; extruder roll; runout; screw; tolerance.**
tolerancing, geometric See **dimensioning and tolerancing, geometric.**
tolerance information See **dimension, reference.**
tolerance, mold filling monitoring See **mold-filling monitoring.**

tolerance, molding Various organizations have published tolerance guidelines. For example, the *SPI Standards and Practices of Plastics Molders* is periodically updated and provides typical values that can be used that pertain to wall thicknesses, holes, flatness, thread size, corners, ribs, fillets, thread sizes, concentricity, draft allowances, surface finish, and color stability. See **fabricating; molding.** Selecting a tolerance requires careful judgment based on logical calculations and understanding factors such as material behavior, processing capabilities, quality control, and cost influence. As a general rule, tolerance should be as large as possible because it can simplify the fabricating process. However, tighter tolerances usually result in significant cost reduction for high production quantities (resin reduction, energy reduction, etc.). See **FALLO approach; plastic material selection.**
tolerance, paint See **solvent tolerance.**
tolerance stack-up It is possible for an accumulation, or stack-up, of tolerances to cause an inoperable or malfunctioning assembly.
toll See **business toll.**
toluene A colorless, flammable liquid with an aromatic benzene odor. It is toxic by ingestion, inhalation, and skin absorption. It is used as an intermediate for polyurethanes and polyesters and as a solvent for certain plastics, vinyl organosols, paints, and coatings.
toluene diisocyanate See **foamed polyurethane.**
toming See **test, microtoming optical analysis.**
ton weight See **mass.**
tomography See **computer-aided tomography.**
tooling Tools include dies, molds, mandrels, jigs, fixtures, punch dies, etc. for shaping and fabricating parts. See **desiccator; die; electroforming; machining; legal matter: mold contractional obligation; mold; prototype.**
tooling, brass A tool that is used during processing to clear or remove melted plastic that may be trapped in the hopper throat when melt bridges or may be sticking to a screw. The brass does not damage the metal, whereas if steel or other metals were used, the steel equipment would be damaged. Beryllium tools are sometimes used, but they are harder than brass.
tooling coat Surface treatments are used to protect the processing tool against abrasion and corrosion due to their contact with the melt. An example is the physical vapor deposition used to optimize the surface properties in a layer up to 10 mm deep that has little effect on the contour of the part. PVD coatings lead to an insignificant and usually indiscernible roughening of the surface. Tools that have been machine finished can therefore be improved. No expensive posttreatment is necessary. In this vacuum-chamber [10^{-2} to 10^{-4} mbar (1 to 0.01 Pa)] process, metals are converted to a gaseous state by the introduction of thermal (electron beam or arc) or kinetic energy (atomization). They condense on the surface being coated. See **coating; die; mold; surface treatment.**
tooling, plastic Plastics, both rigid and flexible, such as epoxy and silicone, have applications as molds, tooling aids (jigs, trim, etc.), prototypes, stretch forms, assembly fixtures, cooling fixtures, and patterns. See **mold material.**
tooling, shell A mold or bonding fixture that consists of a contoured surface shell supported by a substructure to provide dimensional stability.
tool steel See **iron; metal.**
torpedo See **die-head mandrel; screw torpedo; spreader.**
torque A force, energy, or moment that produces or tends to produce rotation or torsion. The twisting force consists of the load applied multiplied by the distance perpendicular to the center of rotational vertical axis. Torque information is very useful to designers in some product designs, such as plasticizing screws and center roller supports. See **joule; screw mechanical requirement; screw torque.**
torque, peel See **sandwich peel torque.**
torque rheometer A quantitative data output instrument that measures temperature of fusion, time of fusion, and torque (work) required. It provides a standardization in extrusion and particularly high-intensity compounding mixers. See **mixer; rheometer.**
torque-shear stress See **moment of inertia; shear stress-strain.**
torr A unit of pressure equal to $^1/_{760}$th of an atmosphere. See **pressure, atmospheric.**
torsion Twisting a material and causing it to be stressed.
torsional analysis See **test, torsional.**
torsional deformation The angular twist of a specimen produced by a specific torque in the torsion test. This deformation is calculated (radian/in.) by dividing observed total angular twist, the twist of one end of the gauge length with respect to the other, by the original gauge length.
torsional modulus of elasticity It is approximately equal to the shear modulus. Also called *modulus of rigidity.* See **modulus of elasticity.**
torsional pendulum A device for performing dynamic mechanical analysis where the test sample is deformed torsionally and allowed to oscillate in free vibration. Modulus is determined by the frequency of the resultant oscillation. The decreasing amplitude of the oscillation determines damping. See **dynamic mechanical measurement; nonresonant forced and vibration technique; resonant forced vibration.**
torsional strength A measure of the ability of a material to withstand a twisting load. Also called *modulus of rupture in torsion* and sometimes in *shear strength.* See **flexural strength; modulus of rupture; temperature flexibility, plastic.**
torsional stress Shear stress on a transverse cross-section caused by a twisting action. See **stress.**
torsional wind-up An effect whereby a torque applied to the drive end of a lead-screw rotates it further than the output end.
tort liability See **legal matter: tort liability.**
total indicator runout See **tolerance, full-indicator movement.**

toughness The ability of a material to absorb energy by plastic deformation rather than crack or fracture. Toughness tends to relate to the area under the stress-strain curve for thermoplastic materials. The ability of a TP to absorb energy is a function of strength and ductility, which tends to be inversely related. For high toughness, a plastic needs both the ability to withstand load and the ability to elongate substantially without failing. An exception is in the case of reinforced thermoset plastics, which have high strength and low elongation. See **brittleness; calcium carbide; chemical and physical characteristics; deformation and toughness; fracture toughness; energy absorption; molecular weight, toughness and temperature; polystyrene plastic, impact; reinforced plastic; stress-strain curve; tensile stress-strain curve; test, ball-burst film impact; test, impact.**

toughness, and area under the curve Toughness is usually proportional to the area under the load-elongation curve, which is the tensile stress-strain curve. However, there are exceptions, primarily with thermoset reinforced plastics where its area is extremely small but the material has extremely high toughness. See **brittleness; hardness; stress-strain curve; tensile stress-strain curve.**

toughening agent An additive that increases the toughness of plastics.

tow See **fiber tow.**

tower A structure that is used in different processes to provide some type of support in the process of fabricating a product. For example, it is required around a blown film bubble and supports a collapsible frame, nip rolls, idler rolls, or treaters. See **extruder-blown film; impregnation.**

toxicity The propensity of a substance to produce adverse biochemical or physiological effects on a human. Although most neat plastics are nontoxic, compounding additives such as certain plasticizers, colorants, and stabilizers could change this condition. If a requirement exists for a material to be nontoxic, select the appropriate compounding mixture. See **biodegradable versus photodegradable; hazard; ISO-10993; nontoxic; plasticizer, nontoxic; plastic, neat; pollution.**

toxicity containment See **geomembrane.**

toxicity, reproductive See **test, carcinogenicity.**

toxicity, smoke See **phosphorous-base flame retardant.**

toxicology The study of the potential of chemicals, plastics, and waste or their mixtures to produce harmful effects in living organisms. Adverse effects are taken to mean those that are detrimental to the survival or normal functioning of a person. See **definition; design, biomedical-product; medical material and the environment; risk, acceptable.**

toy Many toy products are made of flexible to rigid plastics. The use of PVC in soft and flexible toys has become increasingly controversial due to concerns regarding phthalates. See **dioxin; plastic myth and fact; plastics and electronic toys; polyvinyl chloride plastic.**

TPX Mitsui Petrochemical Industries, Ltd.'s tradename for its family of polymethylpentene plastic.

tracer A foreign substance, usually radioactive, that is mixed with or attached to plastic material so its distribution or location can later be determined. It is used as a trace chemical to determine behavior of the plastic melt flow through plasticators, molds, and dies. Also called a *tracer element* or *accessory element*. See **reinforced-plastic prepreg tracer.**

tracking See **electrical tracking.**

trade See **world trade.**

trade, free See **legal matter: tariff.**

trade magazine See **Appendix F, Trade Magazines and Publications.**

trademark See **legal matter: patent infringement; legal matter: trademark.**

trade name See **legal matter: trade name.**

trade show See **shows and conferences.**

train A complete processing line, such as an extruding sheet train, with all its upstream to downstream equipment including all controls. See **calendering-in-train; extruder pipe and tubing; extruder wire and cable train; fabricating processing type.**

training In-house training is conducted by qualified personnel in plants. Outside training sources include colleges and organizations (such as the Plastics Institute of America in Lowell, MA) that have specialized training programs. Techware Designs, a subsidiary of Spirex Corp., has a computer software package called the Extruder's Technician that provides services for installation and use as well as software upgrades. It is ideal for the processors, as well as engineers, salespeople, purchasing agents, managers, and anyone involved in extrusion. Like Techware's injection-molding software program, it explains specific extrusion processes that include blown and cast film, sheet, coating with wire and cable, pipe and tube, profile, and so on. It includes cost-estimating capabilities, engineering calculations that can easily be understood and used, reference guides, troubleshooting information with problems and solutions, and so on. Hands-on training follows comprehensive classroom education. See **computer-based training; computer software; cost-effective training; education; Plastics Institute of America; process simulator; quality; productivity; responsibility; Society of Plastics Engineers; World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**

training, crisis A disaster crisis exercise. Participants may regard these exercises as intrusions that disrupt the normal work routine and add additional duties onto an already heavy workload. The value of crisis drills needs to be understood. With worldwide operations, a corporate crisis can have global implications (e.g., late '70s union carbide chemical release incident). See **management crisis.**

transcrystalline growth A technique that is commonly used for polyolefins, polyamides, and polyurethanes. In adhesive bonding, it is a surface-preparation technique in which adherends are molded against a high-energy metallic substrate that induces transcrystalline growth in the surface regions of the plastic. The formation of the crystallites at the surface results in rodlike or columnar spherulites that form inward from the plastic-metal interface. These are thought to strengthen the surface by driving low-molecular-weight material into the interior. Surface oxidation may also occur, increasing surface reactivity and wettability. This growth effectiveness is dependent on molding conditions, such as cooling rate and mold surface. See **adhesive; surface preparation; surface treatment.**

transducer A device that converts something measurable into another form. It often converts a physical property, such as temperature, pressure, or flow. For example, a piezoelectric device can convert high-frequency electrical energy into high-frequency mechanical vibrations. Also called *sensor.* See **barrel control transducer; computer monitoring information; control, transducer specification; injection molding, linear velocity displacement transducer; linear variable differential transducer; measurement; mold filling monitoring; piezoelectric effect; sensor; transducer, pressure; welding, ultrasonic.**

transducer calibration The standardizing of a sensor. If possible, a calibration check should be made on a regular basis. ISO 9000 dictates frequent checks. A visual examination should be made before proceeding with the check to determine if the diaphragm is flat and free from any damage. Zero balance, full-scale sensitivity, and R-cal at 80% parameter reference points for calibration can be used. The transducer manufacturer provides these parameters. See **ISO-9000 certification.** Some of the more common problems caused by a plant's hostile environment that can affect equipment such as transducers are noise interference, mounting holes (must be concentric and clean), installation, diaphragm considerations, and transducer calibration. See **noise; plant control; plant environment.**

transducer, magnetostrictive (MST) An electrical linear position sensor that is used on machines such as the injection-molding machine. Although sometimes referred to as an *LVDT, LTD,* or a *control linear pot,* the accurate term is a *magnetostrictive transducer.* The physical effect that it measures was first identified by British physicist J. P. Joule during the nineteenth century. The effect is a cross-sectional and longitudinal deformation of a ferromagnetic material in the presence of a defined magnetic field. This property has also been used in apparatus that generates ultrasound and that measures quickly changing forces, strain gauges, and ultrasonic welding. The MST is a waveguide that senses and programs linear position such as the IMM screw position, feedback on clamp stroke, part ejection, and other positioning applications. It uses pulse timing to measure position. It is a noncontact, absolute position, shock- and noise-resistant sensor that does not need rehoming. See **injection molding, linear velocity displacement transducer; linear variable differential transducer; sensor, intelligent; welding, ultrasonic.**

transducer, pressure A sensor that is used in plasticators to improve output and melt quality, enhance production safety, and safeguard machinery (extruder, injection molding, blow molding, etc.). These transducers aid in obtaining optimum processing pressure to ensure product quality, such as output dimensions, surface finish, and minimum material waste. For example, transducers placed at the extruder entrance to the die, in conjunction with a pressure-control device, help maintain more stable output. Pressure measurements at the screen pack and melt pump are also important to provide a constant melt flow. A pressure gauge mounted downstream of the screen pact will alert operators if flow from the screw to the die is restricted, while a transducer upstream of the screen pack will warn of a high-pressure situation that could result in excessive wear to the screw's thrust bearing. See **mold-pressure transducer; reinforced-plastic pressure-curing transducer.**

transducer specification See **control, transducer-specification.**

transfer molding A method of compression molding principally for thermoset plastics. The plastic is first softened by heat and pressure in a transfer chamber (pot) and then forced by the chamber ram at high pressure through suitable sprues, runners, or gates into a closed mold to produce the molded part or parts using two or more cavities. Usually dielectrically preheated circular preforms are fed into the pot. Also called *compression-transfer molding.* See **compression molding; heating, dielectric; molding; outgassing; plunger; preform; pressure, locking; thermoset plastic.**

transfer molding cull The plastic that remains in the transfer chamber after the mold is filled. Unless there is a slight excess in this chamber, one cannot be sure that the cavity was completely full.

transfer molding loading space The space that is provided in a compression-molding mold or in the pot used with a transfer mold, to accommodate the molding material before it is compressed. Also called *loading chamber.*

transfer molding melt flow See **test, spiral melt-flow.**

transfer molding pot The chamber that holds and heats molding material for a transfer mold.

transfer molding pot plunger A plunger in the pot that is used to force softened material into a transfer mold cavity.

transfer molding pot retainer A plate that is channeled for heat and used to hold the pot of a transfer mold.

transfer molding pressure The pressure applied to the cross-sectional area of the material pot expressed in psi or MPa. See **pressure.**

transfer molding, screw-plunger In the screw-plunger transfer molding method, there is a combination in one machine of first using a reciprocating screw injection molding plasticator to prepare the melt prior to entering the transfer molding pot. From the pot it follows the usual transfer molding cycle. Also called *screw transfer molding.*

transfer molding Shaw pot A thermoset plastic transfer molding started by Shaw of Pennsylvania during the 1930s.

transfer molding venting See **mold breathing; vent hole; venting.**

transfer-point control See **injection molding process-control parting line.**

transfer printing A decorating technique that can be described as transfer, tamp, or pad printing. See **printing; printing, pad-transfer.**

transfer time See **cycle.**

transformer See **linear variable differential transducer.**

transformer coil See **impregnation, trickle.**

transient response See **output transient response.**

transient state A state where one or more variables vary with time.

transistor A semiconductor device that is used to amplify the current that is required in different sensing instruments. The two principle types are field effect and junction. See **sensor; thyristor; transducer.**

transition, first-order A reversible change in phase of a material. In the case of plastics, this is usually crystallization or melting.

transition, second-order This term has been replaced by *glass transition temperature.*

translucent Transmitting light diffusely but not permitting a clear view of objects beyond the specimen. See **light transmission; opaque.**

translucent-to-transparent change See **glass, switchable.**

transmission, electron-microscope (TEM) A technique that greatly magnifies images of objects by means of electronics: (1) it permits the visual examination of structures too fine to be resolved with the light microscope, and (2) it permits the study of surfaces that emit electrons. See **image; inspection, visual.**

transmission rate See **test, oxygen gas transmission rate.**

transmission, water-vapor See **test, water-vapor transmission rate; water-vapor transmission.**

transmittance of light The fraction of the emitted light of a given wavelength that is not reflected or absorbed, but that passes through a substance. See **light transmission; optical property.**

transmitter A device that translates the low-level output of a sensor or transducer to a higher-level signal suitable for transmission to a site where it can be further processed. See **molded-material surface measurement.**

transparency improvement For a given crystalline plastic (thermoplastic), reducing the size and number of the crystal structures will improve their transparency—that is, make the plastic more clear. Quickly cooling or using additives such as nucleating agents may sometimes achieve this. For example, by incorporating stiff, aromatic segments in the molecular structure of a nylon chain, which discourages crystallinity, it is possible to make a transparent thermoplastic nylon. Matching the light refractive index of two plastics, or an additive to a plastic material, will give a transparent compound. The transparency may match only over a limited temperature range. See **light index of refraction; molecular structure; nucleating agent; nylon plastic, amorphous.**

transparent An amorphous plastic material that transmits through it a high degree of light that can be easily viewed. When bending transparent plastic, one may want the finished product to have regular transmission, as if no material was in the way of vision and without distorting the object to be viewed. Bending is done successfully on small to large parts, such as military aircraft canopies, in which distortions could be damaging to the pilot. See **additive clarifier; amino plastic; amorphous plastic; crystalline plastic; decorating, second-surface; electrical transparent conductor; fiber optic; Fresnel lens; glass, switchable; injection-molding aircraft canopy; light schlieren system; light transmission nylon plastic, amorphous; opaque; optically active plastic; plastic, light-switchable; polarized light; printing ink, transparent; test, nondestructive transparent medium light schlieren; translucent.**

transparent internal waviness An appearance of waviness in a transparent plastic.

transparent plastic Transparent plastic performance is based on percent light transmission, refractive index, and percent haze. Based on these three optical properties, PMMA is up to 92, 1.49, and 1 to 3; ABS is up to 88, 1.54, and 7; PC is up to 91, 1.59, and 1.5; PS is up to 92, 1.57, and 3; SAN up to 88, 1.57, and 1. Amorphous thermoplastics can be transparent; they are available in a wider color range than the crystalline types, which have been modified to make them transparent. See **acrylic plastic; acrylonitrile-butadiene-styrene plastic transparent; allyl diglycol carbonate plastic; allyl ester plastic; amino plastic; amorphous plastic; amorphous plastic nylon; crystalline plastic; optical property; pigment, organic; polypropylene plastic.**

transparent plastic, light test See **test, nondestructive transparent medium light schlieren.**

transparent slip-plane A plane within transparent material that is visible in reflected light due to poor welding and shrinkage on cooling. See **welding.**

transportation lag See **time, dead.**

transportation market Plastics offer a wide variety of benefits for vehicles, such as durability, corrosion resistance, light weight, fuel savings, recyclability, safety (glass, crash. etc.), and attractiveness. See **automotive market; rail car; tanker truck, reinforced-plastic; trucks and plastic.**

transportation, material contamination See **contamination; material contamination; rail-car contamination.**

transport property A plastic's ability to move through some medium or to have some penetrant medium move between its constituent segments. This definition encompasses processes with diverse driving forces, such as concentration and pressure gradients and even electrical or temperature gradients capable of motivating one relative to another. See **flow; material handling; storage; warehousing.**

treater See **impregnation.**

triallyl cyanurate (TAC) A colorless liquid or solid that is highly reactive. It is used to copolymerize and cross-link with different plastics, resulting in improved properties such as heat-resistant polybenzimidazole plastic, which was developed in 1952. See **polybenzimidazole plastic.**

trifluorochloroethylene plastic A fluorocarbon that is used as a base for polychlorotrifluoroethylene plastic, marked as Kel-F.

trim To remove flash or sharp edges from a molding either by hand or principally mechanically. See **defect; deflashing; flash; molding flash; tumbling.**

troubleshooting The art and science of remedying defects after the process has demonstrated the ability to produce acceptable production parts. Most defects respond to one of a variety of process or material changes. The target is knowing when a particular solution will work and correctly identifying which problem is actually causing the defect. When making adjustments, (1) create a mental image of what should be happening, (2) look for obvious differences, (3) make only one change at a time, and (4) allow the process to stabilize after any change is made. Studies have determined that probably 60% of defects result from the machine or equipment, 20% mold or die, 10% material, and 10% operator. Software programs already installed on the machine's process controller or available as a software package can provide some help. Proper definitions can eliminate some problems.

With all types of equipment, materials, and products, troubleshooting guides are set up (usually required) to take fast, corrective action when products do not meet their performance requirements. This problem-solving approach fits into the overall fabricating-design interface as summarized in the FALLO approach. For example, when possible start by feeding low-bulk density plastic in a starved fed extruder. To avoid aeration and therefore increased potential for volumetric feed limitation, minimize the free fall path from the feeder to the extruder feed throat. If a barrel zone on the barrel constantly overrides or requires too much cooling to maintain a set point, it may be that the melting is being concentrated in that section. This can exist either because of screw design or an improper barrel heat profile. A simple solution is to increase the melting prior to the "hot zone" of the screw. See **air entrapment; automation, vision; barrel and feed-unit operation protection; barrel borescoping; clamping platen, troubleshooting; clean-area fabricating; computer-aided manufacturing; computer software; control-system reliability; DART software; decorating preparation problem; defect; education; extruder cooling and takeoff equipment; fabricating output; FALLO approach; maintenance; moisture analyzer; problems and solutions; processing-line downtime; processor certification; process simulator; quality-control manual; reliability; safety machine-lockout; serviceability; servo-control-drive reliability; training.**

troubleshooting by remote control To aid manufacturing plants, remote troubleshooting is available from different equipment manufacturers and service facilities. Users of certain microprocessor equipment need not be concerned about their plant personnel's ability to service and maintain the equipment. Via telephone link from a computer controller to the service's central computer, a specialist or automatic device can immediately check out conditions in your controller as well as in the complete production line. This remote diagnostic link can also be used to set up preventive maintenance programs. See **auxiliary equipment; fabricating process type; maintenance, preventive.**

troubleshooting guide Various guides are provided by equipment and material suppliers. A simplified approach to troubleshooting is to develop a checklist that incorporates the rules of a problem-to-solution procedure: (1) have a plan, and keep updating it based on the experience gained in operating the equipment; (2) watch the processing conditions; (3) change only one condition at a time; (4) allow sufficient time for each change, and keep some kind of a log of the action, with results, that are occurring; (5) check housekeeping, storage areas, granulators, personnel clothing, and behavior; (6) narrow the range of areas in which the problem belongs, such as material storage and handling, extruder, die, cooling tank, puller, specific control, part design, environment (humidity, ventilation location and direction of forced air, dust, etc.), people, and management. See **problems and solutions.**

troubleshooting optical sheet Black specks, bubbles/voids, die lines, surging, and surface imperfections are among the major problems that processors of optical sheets (film, etc.) encounter. Most problems can be traced to the way the plastic was dried and handled. See **drying; drying operation, hygroscopic plastic; light microscopy; material handling.**

trowelling A method of spreading a plastic material, usually manually, using a tool similar to a bricklayer's trowel. However, trowelling is also automated. See **adhesive trowel.**

trucks and plastic Plastics began to be used in trucks in the late 1940s. DVR designed and built for Strick Trailers (32 to 40 ft) plastic floors, side panels, translucent roofs, etc. Practically all parts were made of reinforced plastics (glass-fiber-thermoset polyester plastic), providing lighter-weight trucks, streamlined frontal area, insulators for refrigerator trucks, and lower part costs. The lighter weight permitted trailers to carry heavier loads. See **automotive market; design, spring; market; rail car; tanker truck, reinforced plastic.**

tube See **extruder pipe and tubing; pipe.**

tube, blown See **extruder tube, blown.**

tube, collapsible-squeeze A tube that is usually identified as air-tight, collapsible, light-proof, unbreakable, convenient and easy to use, sterilizable, and economical. Tubes are big business worldwide, with about 30wt% plastic (predominately polyethylene or polypropylene extruded tube bonded to a injection-molded cap), 30% metal (aluminum), and 40% laminated (paper, aluminum, with predominately plastic film tape wrap, etc.). Some of the aluminum tubes must be coated inside with a plastic barrier material to protect the aluminum from certain packaged products; exteriors may be plastic coated to provide special decorations. See **barrier plastic; design, corrugated.**

tubing Plastic tubing was introduced during the 1930s as a replacement for certain natural-rubber tubing and hose. Natural rubber continues to be used, but the larger market is for elastomeric plastics, including PEs, PPs, PCs, silicones, and fluoropolymers. These flexible tubes can be stressed or bent without breaking. The extent of flexibility required is important in selecting the tubing material so that kinks do not occur when the tubes are in service. Kinks occur because the bending radius reaches the point, based on the material used, where the tubing wall collapses. See **design, corrugated; extruder pipe and tubing; kink.**

tubing, heat-shrinkable A tubing that is made from various plastics, including TFE and TFE copolymers, whose inside diameters are reduced by the application of heat. See **orientation and heat-shrinkability; shrinkage.**

tubing, microbore Small-diameter (micron sizes) tubing is extruded to meet the very tight tolerances (ID and OD) that are required in various products, such as electronics, medical devices, and optical images. Extremely tight quality control is required from start to finish, and factors considered include raw materials to material handling inline, designing the complete extrusion line (die, instrumentation, control parameters, pullers, etc.), inspection procedures, statistical quality control, and so on. See **computer control; computer processing control, statistical; controller; extruder; extruder pipe and tubing; mean and standard deviation; process control; quality control; statistical material selection, reliability of; statistical material selection, uncertainty in; statistical probability; statistical quality control; zero defect.**

tumbling A finishing or deflashing machine operation for relatively small plastic parts by which molded gates, flash, and fins are removed or surfaces are polished by rotating them in a barrel together with wooden pegs, sawdust, ivory nut chips, felt blocks, and polishing compounds. There are batch and continuous systems. Also called *barreling* or *tumbler.* See **blending; burnish; deflashing, cryogenic; material tumbling; mill; mixer, V-blender; trim.**

tumbling agitator A cylindrical or cone-shaped vessel that rotates about a horizontal or inclined axis with internal ribs that lift the material and then let it tumble back into the charge. Their main use is with dry blends, such as adding color concentrates in molding compounds.

tumbling blender-mixer A device that is used in blending powders and pellets. There are three main types: drum, double-cone, and V-blender-mixers. See **material blending letdown ratio; mixer.**

tumbling, drum A device that is extensively used to mix plastic pellets with color concentrates and recycled plastics. The materials are charged into a cylindrical drum, which are tumbled end over end or rotated about an inclined axis for a specified time to thoroughly blend the component.

tumbling, wet Finishing plastics in a barrel that contains a wet abrasive, such as a pumice slurry. See **pumice.**

tungsten alloy See **injection-molding nonplastic; reinforced-plastic cutting.**

turbulent flow See **coolant, turbulent-flow; melt flow, laminar.**

turnkey operation See **fabricating turnkey operation.**

turn per inch See **twist, direction of yarn.**

turret winder See **orientation, biaxial.**

twist, direction of yarn In yarn or other textile strands, the spiral turns about its axis per unit of length. Twist may be expressed as turns per inch (tpi). The letters S and Z indicate the direction of the twist, in reference to whether the direction conforms to the middle-section slope of the particular letter. A yarn or strand has an S twist if when held in a vertical position, the spirals conform in slope to the central position of the letter S. It has a Z twist if the spirals conform in slope to the central portion of the letter Z. Strands that are simply twisted (greater than 1 turn/in. or 40 turns/m) will kink, corkscrew, or unravel because their twist is in only one direction. The plying operation normally eliminates this problem. For example, single yarns having a Z twist are plied with an S twist, thus resulting in a balanced yarn. Depending on the twisting and plying operations, different yarn strengths, diameter, and flexibility can be obtained to meet different performance requirements of plastic materials, such as coated fabrics, reinforced plastics, and pultrusions. See **directional property; fiber; impregnation; kink; reinforced plastic characterization; yarn twist, hawser.**

twist, zero Twistless; devoid of twist.

two-color molding See **injection molding, two-shot.**

two-shot molding See **injection molding, two-shot.**

typical basis The typical property value is an average value. No statistical assurance is associated with this basis. See **A-basis; B-basis; C-basis; population confidence interval.**

Tyvek DuPont's tradename for its spun bonded, tough, strong HDPE fiber sheet product. It is used in mailing envelopes (protects contents, etc.), medical devices, and wrapping around buildings. See **fabric, nonwoven spunbonded.**

U

UL 94 See **fire retardance; Underwriters' Laboratory Classification.**
Ultem GE Plastics' trade name for its family of polyether-imide plastics.
ultimate strength See **tensile strength.**
ultraocular lens See **medical, lens implant.**
ultrasonics The science of the effects of mechanical or sound vibrations beyond the limit of audible frequencies, greater than approximately 20,000 Hz. It is used in friction welding, drilling hard materials, nondestructive testing, cleaning of tools, and cavitation erosion tests. See **cavitation; relaxation, ultrasonic; welding, ultrasonic.**
ultrasonic C-scan See **test, nondestructive ultrasonic.**
ultrasonic degradation A type of mechanochemical degradation that occurs when a plastic solution is irradiated with ultrasonic radiation. Cavitation (rapid collapse of regions of low pressure) occurs and the resulting very high local shearing forces can cause mechanochemical chain scission of the plastic, reducing molecular weight. See **degradation.**
ultrasonic fabrication Ultrasonic assembly of plastic parts is done by welding, metal inserting, staking, spot welding, and sewing. In each application ultrasonic vibrations above the audible range generate localized heat by vibrating one surface against another. Sufficient heat is released, usually within a fraction of a second, to cause most thermoplastics to melt, flow, and fuse. See **fabricating process; welding.**
ultrasonic, light See **test, nondestructive transparent medium light schlieren.**
ultrasonic penetration See **test, nondestructive ultrasonic penetration.**
ultrasonic surface measurement See **molded-material surface measurement.**
ultrasonic testing See **test, nondestructive ultrasonic.**
ultrasonic wave A sound wave that has a frequency higher than those that can be heard by humans—that is, all waves with a frequency of 18,000 cycles/s and above. For commercial use, such waves are produced mechanically or by an electrical or electronic generator driving a transducer. See **welding, ultrasonic.**
ultrasound Mechanical vibrations having the same physical nature as sound but with frequencies normally above the range of human hearing. See **transducer, magnetostrictive.**
ultraviolet (UV) The zone of invisible radiation beyond the violet end of the spectrum of visible radiation. Because UV wavelengths are shorter than visible wavelengths, their photons have more energy, which initiates some chemical reactions and can degrade certain plastics. It pertains to the region of the invisible electromagnetic spectrum from about 10 to 400 nm. The term UV without further qualification usually refers to the region from 200 to 400 nm. See **chemistry, analytical; dryer, ultraviolet; electromagnetic spectrum; optical brightener agent; spectrometer, ultraviolet; ultraviolet radiation; weatherability.**
ultraviolet absorber A low-molecular-weight organic compound, such as hydroxybenzophenone derivatives, that is capable of absorbing a significant amount of radiant energy in the ultraviolet wavelength region. This protects the material, such as plastic (in which it is an additive), from the damaging (degrading) effect of the energy. An UV absorber without significant chemical change dissipates the absorbed energy. Also called *UV stabilizer.* See **optical brightener agent; stabilizer.**

Light itself does not directly harm plastics, but the radiations and particularly UVs tend to initiate or catalyze chemical degradation. The result is oxidation, a process that is often referred to as *photooxidation.* It is the degradation occurring in the presence of oxygen. Various plastics are susceptible to this degradation. Absorbers and stabilizers are used to ensure long outdoor exposure, such as at least 50 years with PMMA. A light-stabilizer screen is insoluble in the plastic and therefore renders a transparent material opaque. Carbon black, especially of small particle size, is the most effective screen. Other pigments, such as zinc oxide, have less screening power and act by reflecting rather than absorbing UV.
ultraviolet radiation Electromagnetic radiation is in the 40 to 400 nm wavelength region. The sun is the main natural source of UV radiation on the earth. Artificial sources are many, including fluorescent UV lamps. UV radiation causes certain plastic photodegradation and other chemical reactions. See **adhesive, one part; printing ink, radiation.**
ultraviolet stabilizer A stabilizer that protects plastics that are affected by the harmful effects of the sun. By intercepting the sun's rays, they extend the plastic's retention of physical properties. Without these additives, the plastic's molecular chains break down at a faster rate. Also called *UV stabilizer, ultraviolet absorber,* or *UV absorber.* See **carbon black; degradation; oxidation degradation, thermal; photooxidation agent; stabilizer.**
ultraviolet stabilizer and color UV stabilizers do not permanently improve color stability for colored plastic parts. Sunrays cannot reach the plastic's interior molecular chains because the radiation cannot pass through the plastic without interacting with an outer plastic chain or the UV stabilized molecules. If a system is properly stabilized, then

the sun's energy is prevented from reaching the interior chains for a period long enough to permit the part to complete the expected service life. With opaque plastics if the colorant used were not light stabilized, they would fade. UV additives might provide negligible protection.

unary system Composed of one component.

undercured See **curing, under-.**

undercut See **mold undercut.**

underground pipe Thermoplastic pipes transport gas, water, and so on. Where very high loads or corrosive situations exist, reinforced-plastic piping is used. See **pipe, geothermal; pipe, water deterioration; reinforced-plastic pipe; safety; sewer rehabilitation.**

underwater processing See **molding, isotactic.**

Underwriters' Laboratory classification UL's Classification and Follow-Up Service is used by manufacturers to show that the product bearing the UL marking complies with UL's requirements. See **Appendix C, Worldwide Plastics Industry Associations.**

Underwriters' Laboratory electric power See **electronic standard, international.**

Underwriters' Laboratory factory inspection UL representatives visit factories and other facilities where listed, classified, or recognized products are made and conduct examinations or tests of such products. They also examine how the manufacturer determines compliance with UL's requirements.

Underwriters' Laboratory fire-resistance index A summary of classified fire-resistance products and building construction-design fire resistance ratings published for general distribution. See **test, fire cone and lift.**

Underwriters' Laboratory Standard UL-544 A general safety standard. See **safety.**

Underwriters' Laboratory UL-94 See **fire retardance.**

uniaxial load See **directional property, uniaxial load.**

Unicarb Union Carbide's trade name for its finish systems that compete with solvent organic systems. See **finish system, reduced solvent.**

unicellular plastic Also called *closed-cell foamed plastic.* See **foam.**

unidirectional fabric See **fabric, woven.**

unidirectional property See **directional property, unidirectional.**

Union Carbide mixing screw See **screw mixing, Maddock.**

Unipol Union Carbide's trade name for its low-pressure process that made possible the start of the large-volume utilization of linear low-density polyethylene and other plastics.

unit **1.** A part on which a measurement or observation may be made. **2.** A precisely specified quantity in terms of which magnitudes of other quantities of the same kind can be stated.

unit, coherent system A system of units of measurement in which a small number of base units, defined as dimensionally independent, are used to derive all other units in the system by rules of multiplication and division with no numerical factors other than unity.

unit elongation See **tensile elongation unit.**

unsaturated See **chemical unsaturation.**

unsaturated compound A substance with more than one bond between adjacent atoms, usually carbon, and thus reactive toward the addition of other atoms at that point. An example is thermoset unsaturated polyester plastic. See **aromatic; compound.**

unsaturation A condition of being partially filled. In terms of a compound, it denotes a condition of being able to take up or react with more atoms. See **saturation.**

The Unwritten Laws of Engineering: the Professional Code for Engineers A book that sets forth a professional code of conduct for engineers that covers everything from handling interpersonal relationships with associates to assigning responsibilities for technical projects. Included are numerous rules, recommendations, and timeless "dos and don'ts" for engineers. The book is written by W.J. King, and published by the American Society of Mechanical Engineers (Fairfield, NJ, 1997). See **ethics.**

upstream That portion of a fabricating line that has not yet entered the main processing equipment, such as an extruder. See **auxiliary equipment; downstream; fabricating process; processing, in-line; processing line, upstream.**

uptime See **processing line uptime.**

urea A natural product that is synthesized as white crystals or powder with a melting point of 132°C (270°F). It is soluble in water, alcohol, and benzene. It is used as a flame-proofing agent and in plastics such as urea formaldehyde plastic. Also called *carbamide.*

urea formaldehyde plastic (UF) A synthetic thermoset plastic that is derived by the reaction of urea with formaldehyde or its polymer. The UF plastics are in the amino family of plastics. They are available in a wide range of colors from translucent colorless and white to a lustrous black. Within their range of operating temperatures of −21°C (−60°F) to 80°C (175°F), they are not affected by heat as with most thermoplastics. Higher temperatures over prolonged periods of time will cause fading and eventually blistering. These nonflammable (self-extinguishing), odorless, and tasteless materials char at about 200°C (395°F). UFs have lower hardness, heat resistance, and moisture resistance than melamine plastics. They have higher tensile strength and hardness than phenolic but have lower impact strength, heat, and moisture resistance. UFs are scratch resistant and solvent resistant, including hot water. It is used in adhesives, cosmetic container closures, tableware, appliance housings, laminates for counters, sanitary ware, toilet seats, buttons, electrical insulators and accessories, tabletops, adhesives, and coatings. Its major use is in wood products, where about 85wt% is consumed as wood adhesives in the production of particleboard, medium-density fiberboard, and hardwood plywood. Also called *urea resin* or *urea plastic.* See **amino plastic; glassine.**

urethane plastic See **polyurethane plastic.**

V

vacuum In vacuum technology, a given space that is filled with gas at pressures below atmospheric pressure. See **atmosphere; casting, vacuum; cleaning, vacuum-pyrolexis; coating, vacuum; coating, vacuum-deposition; distillation, vacuum; extruder vacuum box; flashing, vacuum; impregnation; material handling, vacuum loader and conveyor; metallizing, vacuum; mold cooling, vacuum; thermoforming, pneumatic control; thermoforming; vacuum; thermogravimetric analysis, vacuum thermobalance; torr; wood compressed; wood-plastic impregnated.**
vacuum condensing point The temperature at which the sublimate (vaporized solid) condenses in a vacuum. Also called *vcp.*
vacuum hot pressing (VHP) A method of processing materials, especially those in powder form, at elevated temperatures, consolidation pressures, and below atmospheric pressure.
vacuum press A molding press, such as a compression molding press, can include a vacuum chamber or system that is used with the mold to remove air or gases. See **mold breathing; molding, sheet-molding compound and vacuum press; reinforced-plastic vacuum-bag molding.**
vacuum sizing A shape-holding fixture that is used to set the dimensions of processed plastics by holding the material against a mandrel by means of a vacuum. Also called *vacuum tank.* See **extruder vacuum box.**
validating marketing See **marketing; World of Plastics Reviews: Making Marketing Work.**
validation, medical See **sterilization radiation.**
valence **1.** The relative ability of a substance to react or combine. **2.** A positive number that characterizes the combining power of an element for other elements, as measured by the number of bonds to the other atoms where one atom of the given element forms a chemical combination. Hydrogen is assigned a valence of 1, and the valence is the number of hydrogen atoms, or their equivalent, with which an atom of the given element combines. The valence-balancing principle gives chemical formulas such as H_2O, Cl_2O, NCl_3, and N_2O_3, which indicate the relative numbers of atoms of these elements in compounds. Valences of 2 and 3 are called *divalent* and *trivalent.* See **chemical composition and properties of plastic; electron; element; Lewis symbol; molecular bonding; van der Waal's force.**
valence band The highest energy band that is normally occupied by electrons. See **chemical reaction, valence electron.**
valence bond See **temperature and molecular bonding force.**
valence, coordinate A chemical bond between two atoms in which a shared pair of electrons forms the bond and the pair has been supplied by one of the two atoms. Also called *coordinate bond.*
valence electron See **chemical reaction, valence electron.**
valence, long pair A valence electron that is not involved in bond formation. Also called *nonbonding electrons.*
valence shell The outer most electron-occupied shell of an atom.
value analysis (VA) VA = (function of product)/(cost of the product). Immediately after the part goes into production, the next step is applying the value engineering approach and the FALLO approach to produce products that meet the same performance requirements but are produced at a lower cost. VA can reduce cost, enhance quality, and boost productivity. See **engineered, re-; FALLO approach; plastic material selection.**
value, approximate A value that is nearly but not exactly correct or accurate.
value, normal A value that is assigned for the purpose of convenient designation but exists in name only.
value, order of magnitude A range of values that are applied to numbers, distances, and dimensions and that begin at any value and exceed to 10 times that value. For example, 2 is of the same order of magnitude as any number between itself and 20, and 5 miles is of the same order of magnitude as any distance between 5 and 50 miles.
value, true See **error, percentage.**
vanadium trioxide (V_2O_3) A toxic, black crystal that is soluble in alkalies and hydrofluoric acid, is slightly soluble in water, and melts at 1,970°C. It is used as a catalyst. Also called *vanadium sesquioxide.*
van der Waals adsorption Adsorption in which the cohesion between gas and solid arises from the van der Waals forces. See **adsorption.**
van der Waals force An attractive force between two atoms or nonpolar molecules, which arise because a fluctuating dipole moment in one molecule induces a dipole moment in the other, and the two dipole moments then interact. They are somewhat weaker than hydrogen bonds and far weaker than interatomic valences. Information regarding their numerical values is mostly semiempirical, derived with the aid of theory from an analysis of physical and chemical data. Also called *intermolecular force, secondary valence force, dispersion force, London dispersion force,* or *van der Waals attraction.* See **Boyle's law; gas pressure and temperature; mixing theory; molecular bonding; valence.**
van Hoff isotherm See **energy, van Hoff isotherm.**
vapor The gaseous form of substances that are normally

in the solid or liquid state and that can be changed to these states either by increasing the pressure or decreasing the temperature. See **water.**

vapor, condensable Gases or vapors that when subjected to appropriately altered conditions of temperature or pressure become liquids.

vapor condensation See **distillation.**

vapor decreasing See **cleaning solvent.**

vapor deposition, chemical See **chemical vapor deposition; xylylene plastic.**

vapor detector, dielectric An instrument that measures the change in the dielectric constant of gases or gas mixtures. It is used as a detector in gas chromatography to sense changes in carrier gas. See **chromatography, gas; dielectric constant.**

vapor diffusion See **water-vapor diffusion.**

vaporization See **evaporation; volatile loss.**

vaporization point At a given pressure, the temperature at which the vapor pressure of the liquid is equal to the external pressure or at a stated temperature the external pressure on the liquid that is equal to its vapor pressure.

vapor-liquid-solid process (VLS) Carborundum Co., Niagara Falls, NY, developed a process that produces high-quality and rather a large quantity of silicon carbide whiskers. See **fiber, silicon-carbide; reinforced plastic, advanced; reinforced, whisker.**

vapor-phase hydrogen peroxide See **sterilization, vapor-phase hydrogen-peroxide.**

vapor pressure The pressure that is exerted by the vapor at a given temperature of a solid or liquid when in equilibrium with the solid or liquid. Also it is the component of atmospheric pressure contributed by the presence of water vapor. See **distillation, vapor rate of; drying; molecular-weight vapor-pressure osometer; Raoult's law; vapor; volatile; water-vapor transmission.**

vapor pressure curve A curve for a substance such as water, showing the variation of boiling temperature with boiling pressure. It indicates combinations of temperature and pressure at which the substance will be in a fluid or vapor phase.

vapor vacuum deposition The condensation and solidification of the metal or metal containing vapors, under high vacuum, to form deposits on a substrate.

variable A quantity to which any of the values in a given set may be assigned. If variable A is a function of variable B, then A is the dependent variable, and B is the independent variable. The deviation variable is the difference between the dependent variable and the steady-state value. See **control response; extruder instability or variability; motion-control system.**

variance The mean square of deviations, or errors, of a set of observations; the sum of square deviations, or errors, of individual observations with respect to their arithmetic mean divided by the number of observations less one (degree of freedom); the square of the standard deviation, or standard error. See **mean; statistical F-test; statistical material selection, reliability of.**

varnish A nonpigmented coating comprising a solvent and (1) a binder that forms a film by oxidation or polymerization or (2) a binder that forms a film by evaporation of the solvent. Type 1 includes drying oils, either alone or in combination with natural or synthetic plastics or chlorinated rubber, and uses such solvents as turpentine and naphtha. Type 2 includes shellac, cellulose ester, or with either alkyd or phenolic plastic, and uses such solvents as methanol, isobutyl ketone, butyl acetate, and toluene. See **aluminum stearate; copal; finish, baking; linseed oil; paint; printing and varnish; shellac.**

varnish, cold-cut A varnish or lacquer manufactured by dissolving the ingredients in a suitable solvent by mechanical agitation without the application of heat.

vector See **mathematical vector.**

vehicle The liquid medium in which pigments, etc., are dispersed in the coating and which enables the coating to be applied. See **coating; paint; varnish.**

veil A very thin mat that is used to improve plastic surface characteristics, particularly for reinforced plastics. See **fiber mat; reinforced plastic.**

Velcro strip A process that uses a continuous injection-molding operation. The equipment molds the strip from the plastic, trims it, conditions it for flatness, applies an adhesive backing, and winds it on a reel. The key elements are a conventional extruder that combines extrusion with injection and a rotating ferris wheel mold. An extruder runs continuously, feeding the melt into the continuously rotating mold through a special adapter, mounted on the extruder barrel melt outlet. For example, a 2 ft (61 cm) diameter mold turns at about 10 rpm, delivering Velcro at 60 to 70 ft/min (18.3 to 21.3 m). The mold contains more than 15,000 cavities meeting very tight tolerances. Plates (forming cavities) in the mold stack are surface-ground to be flat within 0.002 in (0.050 mm) across a 2 ft (0.6 m) diameter. Also, plate thickness, which determines the spacing between adjacent rows of splines as well as the quality of the seal between adjacent plates, is controlled to within 0.0001 in. (0.0025 mm).

As the mold rotates past the extrusion-injection die head, the melt flows onto the circumference of the mold and is forced by the melt pressure into the cavities. Enough additional melt is supplied to create the base strip at the same time. By the time the mold has completed about one-half a revolution, the plastic has been cooled and solidified. Mold temperature is controlled by an air plenum located about one-quarter of a revolution before the injection point; the molded Velcro itself is cooled by another plenum ahead of the strip-off point. The airflow is adjusted to keep the nylon (usual plastic used) sufficiently warm and flexible so that the projections can pull free from the undercuts in the cavities without damage during strip-off. See **extruder; injection-molding, continuous; mold; zipper.**

velocity See **calculus.**

veneer Thinly cut wood (usually premium wood) that is applied to a surface laminate such as plastic or wood. Thin sheets are also used to produce plywood using low-

to premium-grade wood. See **adhesive, edge joining; laminate; wood, ply-; wood veneer.**
Venetian red See **pigment, Venetian red.**
vent bleed The unplanned escape of melt through the air vents that are used during certain fabricating processes, such as in molds or vented barrels. See **barrel-vent safety; bleed; mold-cavity venting; screw, venting.**
vent cloth A layer or layers of open-weave cloth that is used to provide a path for a vacuum to reach the area in which a reinforced plastic is being cured, such that volatiles and air can be removed. It causes a pressure differential that results in the application of pressure to the part being cured. It is used in processes such as bag molding, autoclave molding, and vacuum bag molding. Also called *breather cloth*. See **reinforced-plastic bag molding; venting.**
vented barrel See **screw, venting.**
vent hole An opening for the escape of gases during processing. Also called *port hole*. See **mold breathing; screw, venting; thermoforming mold.**
venting **1.** Removing entrapped air and other gases that may be produced during fabrication. See **extruder venting; injection-molding venting; screw, venting; venting purifier; volatile. 2.** Shallow holes, tubes, or channels in a mold that allows gases and air to exit as the molding material enters the cavity. See **air vent; mold breathing; mold-cavity venting; rotational-molding venting. 3.** See **barrel-venting safety; drying operation, hygroscopic plastic; mold venting, water transfer; safety. 4.** A woven or nonwoven fabric layer that is used to vent reinforced plastics during fabrication. This bleeder cloth is removed after the curing process; it is not part of the final RP part. See **reinforced-plastic venting cloth; vent cloth.**
venting, blow molding See **blow molding, extruder-mold.**
venting feeder A controlled material feeding device that maximizes the operation of a vented system in equipment such as an extruder or injection-molding machine. The controlled feeding device determines the amount of plastic that is being fed into the screw, thereby controlling the output of the first stage of a two-stage screw. This action should eliminate all cases of possible vent bleeding and plugging of the vent hole. By partially filling the screw flight channels, the surface moisture that is being driven off the plastic has a vapor space in which to evaporate. It facilitates control of the amount of shear and energy that is delivered to the plastic via the screw geometry, different shear history can be provided, etc. Also called *starve feeder*. See **material starve feeding.**
venting purifier A device that removes and collects exhaust steam and other vapors. The exhaust from vented plasticating barrels is almost all condensed steam, but a small portion of the vent exhaust can be by-products that are released by certain plastics or additives and that can be of concern to plant personnel or plant equipment. The purifiers include electronic precipitators. See **purging; purification; screw, venting.**
venting safety See **barrel-venting safety; plasticator safety.**
venting via water transfer See **mold venting, water transfer.**
venturi A type of flow meter. It is a tubelike device having broad, flaring ends and a narrow central portion (or throat). This shape constricts the passage of a "fluid" so that its rate of flow increases while the pressure decreases. The difference in pressure creates a measure of the flow. It is used in many different types of processing equipment, such as material conveying systems and scrubbers. See **cooling ring, venturi; extruded-blown film air ring; flow meter; material handling, pneumatic loader and conveyer; pollution, air.**
verification See **design verification.**
vermiculite One of the mica groups that are used as granular filler of relatively high compressive strength. They are a crystalline layer silicate mineral of similar structure to talc. However, some of the silicon atoms are replaced with aluminum, producing a negative charge that is neutralized by the interlayer cations, mostly magnesium. The ionic forces bind the layers together strongly. Water molecules in the layers are hydrogen bonded to oxygen of the silicates. On rapid heating to about 300°C (572°F) the steam produced causes separation of the layers, giving an expansion (exfoliation) of up to 30 times. It is used as a special type filler; as an example when mixed with plastic to form a filler compound having relatively high compression strength. See **filler; silicate; talc.**
vertical rotary wheel molding See **blow molding, extruder, vertical rotary wheel; clamping platen, rotary; injection molding, two-shot; press, rotary.**
vessel See **boat; marine applications for plastics.**
vessel tank See **ABL bottle.**
vibration An oscillation wherein the quantity is a parameter that defines the motion of a mechanical system. See **attenuation; damping capacity; dash pot; nonresonant forced and vibration technique; orientation and electrical property; resonant-forced vibration; wave.**
vibration, free A technique for performing dynamic mechanical measurements in which a sample is deformed, released, and allowed to oscillate freely at the natural resonant frequency of the system. Elastic modulus is calculated from the measured resonant frequency; damping is calculated from the rate at which the amplitude of the oscillation decays. See **damping; resonance; resonant-forced vibration.**
vibration frequency See **stroboscope.**
vibration, melt See **injection molding, vibrational; melt vibration.**
vibration, optical See **wave.**
vibration welding See **sealing, ultrasonic; welding, vibration.**
vibratory cavitation test device See **test, nondestructive ultrasonic.**
Vicat test See **test, hardness Vicat; test, softening point Vicat.**

vinyl See **polyvinyl chloride plastic; vinyl plastic.**

vinyl acetate A colorless, water soluble, flammable liquid that boils at 73°C (163°F). It is used as an intermediate additive and in the production of plastics such as polyvinyl plastic.

vinyl acetate plastic See **polyvinyl acetate plastic.**

vinyl alcohol A flammable, unstable liquid found only in ester or polymer form. Also called *ethanol.*

vinylation The formation of a vinyl-derived product by the reaction with acetylene. For example, vinylation of alcohols gives vinyl ethers, such as vinyl ethyl ether plastic.

vinyl chloride monomer (VCM) A flammable, explosive gas with an ethereal aroma. It is soluble in alcohol and ether and slightly soluble in water and boils at −14°C (7°F). It is an important monomer for PVC and its copolymer plastics. It is also used in organic synthesis and in adhesives. Regnault first prepared VCM in 1835. In 1921, Plausen discovered how to polymerize VCM into PVC. Commercial production started in 1931. Many new developments occurred thereafter. Also called *chloroethene* or *chloroethylene.* See **ethylene dichloride; polyvinyl chloride plastic.**

vinyl composition tile (VCT) Both environmentally and economically, VCT outperforms two other flooring products, according to a new life-cycle assessment by the U.S. National Institute of Standards and Technology. Using a newly developed software program termed BEES (Building for Environmental and Economical Sustainability), NIST compared VCT with linoleum and recycled-content ceramic tile. The results show VCT ranks 20 to 30% higher in environmental performance and 90 to 170% higher in economic performance. Criteria for the rating include indoor air quality, solid waste, acid rain, global warming, and natural resource depletion. The BEES model for evaluating building products has been adopted as an official tool of the U.S. Greenbuilding Council and is used by architects, builders, contractors, and other specifiers who want to select environmentally friendly products. See **dioxin; life-cycle analysis; polyvinyl chloride plastic; vinyl seagoing bag.**

vinyl dispersion See **plastisol.**

vinyl ester plastic A stiff and tough unsaturated thermoset plastic that is cured by both peroxide catalyzed addition polymerization of vinyl groups and anhydride cross-linking of hydroxyl groups at room or elevated temperatures. Cured bisphenol-A vinyl esters are characterized by chemical resistance; epoxy novolak vinyl esters by solvent and heat resistance; and all types in general are tough and flexible in a wide range. Their major use is as the matrix in glass-fiber reinforced plastics. They provide exceptional high-strength properties in highly corrosive or chemical environments when compared to other commercial RP matrices. Popular processes include filament winding, transfer molding, pultrusion coating, and laminating. Uses include structural composites, sheet-molding compounds, and chemical apparatus. See **polyvinylidene chloride plastic, reinforced plastic, vinylidene chloride plastic.**

vinyl monomer See **ionic initiator.**

vinyl plastic Vinyls are a large class of diversified thermoplastics with the most important being polyvinyl chloride plastics. Other families are vinyl acetate, vinyl alcohol, vinylidene chloride, and vinyl acetal plastics. Their properties vary widely. In general, they show good weatherability, barrier properties, flexibility, and low costs; they are attacked by many solvents and have limited thermal stability. They are used in film and sheet products. See **chlorine; fusion; organosol; plastisol; polyvinyl chloride plastic.**

vinyl plasticizer See **plasticizer, phthalic.**

vinyl plastic, stir-in A vinyl plastic that does not require grinding to effect dispersion in a plastisol or organosol.

vinyl recycling aid See **recycling steel with vinyl scrap.**

vinyl seagoing bag Nordic Water Supply (NWS of Norway) has a ten-year contract to use plastic water containers or bags to transport surplus water from Turkey to Cyprus. Tugboats pull several of the water-filled bags. The bags which had a volume of 13,000 cubic yards of water when the project started, now have 26,000 cubic yards, and are targeted to go to 105,000 cubic yards of water per bag. Bags are made of thermoplastic polyester fabric textiles with internal and external layers of vinyl especially designed for seawater. This project has shown that transporting water in vinyl bags is cost effective. See **dioxin; polyvinyl chloride plastic; vinyl composition tile.**

virus See **computer virus.**

viscoelastic creep When a plastic material is subjected to a constant stress, it undergoes a time-dependent increase in strain. This behavior is called *creep.* See **creep; strain.**

viscoelastic fluid A fluid that exhibits predominantly viscous flow behavior but also exhibits some elastic recovery of the deformation on release of the stress. To emphasize that viscous effects predominate, the term *elasticoviscous* is sometimes preferred; the term *viscoelastic* is reserved for solids showing both elastic and viscous behavior. Most plastic systems, both melts and solutions, are viscoelastic because their molecules become oriented due to the shear action of the fluid but regain their equilibrium in randomly coiled configuration on release of the stress. Elastic effects are developed during processing such as in die swell, melt fracture, and frozen-in orientation. See **design die; design mold; rheology; stress-strain curve; viscoelastic material.**

viscoelasticity A combination of the viscous and elastic properties in a plastic with the relative contribution of each being dependent on time, temperature, stress, and strain rate. It relates to the mechanical behavior of plastics in which there is a time- and temperature-dependent relationship between stress and strain. A material having this property is considered to combine the features of a perfectly elastic solid and a perfect fluid. The response to stress of all plastic structures is viscoelastic, meaning that it takes time for the strain to accommodate the applied stress field. The time constants for this response will vary with the specific characteristics of the plastic and processing techniques. In the rigid section of a block polymer the response time is usually on the order of microseconds to milliseconds. With resilient rubber sections of the structure the response time can be long, ranging from tenths of a second to seconds. This difference in response time is the cause of failure under rapid loading for certain plastics.

To understand why the possibility for brittle failure does, in fact, exist when the response under high-speed stressing is transferred from resilient regions of a block polymer, an analysis of the response of the two types of materials in the structure is necessary. The elastomeric regions, which stay soft and rubbery at room temperature, will have a very low elastomeric modulus and a very large extension to failure. The rigid, virtually cross-linked regions, which harden together into a crystalline region on cooling, will be brittle and have very high moduli and very low extension to failure, usually from 1 to 10%. If the stress rate is a small fraction of the normal response time for the rubbery regions, they will not be able to strain quickly enough to accommodate the applied stress. As a consequence the brittle, virtually cross-linked regions take a large amount of the stress, and since they have limited elongation, they fail. The apparent effect is that of a high-stretch, rubbery material undergoing brittle failure at an elongation that is a small fraction of the possible values. See **brittleness; designing with the pseudoelastic method; dielectric Maxwell-Wagner effect; elasticity; elastic solid; modulus; pseudoplastic; rheology; strain; stress.**

viscoelasticity, linear The theory of linear viscoelasticity is valid only when the deformation is either small or slow. In the case of oscillatory shear experiments, for example, the strain amplitude must usually be low. For large and more rapid deformations, the linear theory has not been validated. The response to an imposed deformation depends on (1) the size of the deformation, (2) the rate of deformation, and (3) the kinematics of the deformation.

The simplest type of viscoelastic behavior is linear viscoelasticity. This type of rheology behavior occurs when the deformation is sufficiently mild that the molecules of a plastic are disturbed from their equilibrium configuration and entanglement state to a negligible extent. Since the deformations that occur during plastic processing are neither small nor slow, any theory of linear viscoelasticity to date is of little use in processing modeling. Its principal utility is as a method for characterizing the molecules in their equilibrium state. An example is in the comparison of different plastics during quality control. See **deformation; kinetic.**

viscoelasticity, nonlinear The behavior in which the relationship of stress, strain, and time are not linear so that the ratios of stress to strain are dependent on the value of stress. The Boltzmann superposition principle does not hold. Such behavior is very common in plastic systems, nonlinearity being found especially at high strains or in crystalline plastics. See **Boltzmann superposition principle; kinetic.**

viscoelastic material A plastic for which at long times of applied stress, such as in creep, a steady flow is eventually achieved. Thus in a generalized Maxwell model, all the dashpot viscosities must have finite values, and in generalized models they must have zero stiffness. For materials with very long relaxation time the distinction between a viscoelastic liquid and a viscoelastic solid becomes uncertain. See **test analysis, micromechanical; viscoelastic fluid.**

viscoelastic modulus See **modulus, stress-relaxation.**

viscoelastic spectrum See **thermomechanical spectrum.**

viscometer An instrument that is used for measuring the viscosity and flow properties of fluids such as plastic melts. A commonly used type is the Brookfield, which measures the force required to rotate a disk or hollow cup immersed in the specimen substance at a predetermined speed. Other types employ such devices as rising bubbles, falling or rolling balls, and cups with orifices through which the fluid flows by gravity. Also called a *viscosimeter.* Instruments for measuring flow properties, of highly viscous fluids and molten plastics are more often called *rheometers* or *plastometers.* See **rheometer; test, melt-flow; test, Mooney viscosity.**

viscometer, capillary An instrument that is used for measuring either concentrated solutions or plastic melts (described under capillary rheometer) or dilute solution viscosities. The most widely used of the latter type employs a glass capillary tube and means for timing the flow of a measured volume of solution through the tube under the force of gravity. This time is then compared with the time taken for the same volume of pure solvent, or of another liquid of known viscosity, to flow through the same capillary tube. See **rheometer, capillary.**

viscometer, Weissenburg effect A phenomenon that is encountered in rotational viscometric studies at high speeds, particularly when the alignment between cups is not perfect, and is characterized by a tendency of the plastic solution to climb the wall of the cup or cylinder that is rotating. See **viscosity, non-Newtonian flow; Weissenburg effect.**

viscose A highly viscous solution composed of cellulose xanthate and dilute caustic soda.

viscose process A process for manufacturing rayon fiber by treating cellulose with caustic soda and with carbon disulfide to form cellulose xanthate, which is then dissolved in a weak caustic solution to form the viscose material. See **fiber, rayon.**

viscosity The property of the resistance of flow exhibited within a body of material. Ordinary viscosity is the internal friction or resistance of a plastic to flow. It is the constant ratio of shearing stress to the rate of shear. Shearing is the motion of a fluid, layer by layer, like a deck of cards. When plastics flow through straight tubes or channels, they are sheared, and the viscosity expresses their resistance. The melt index or melt-flow index is an inverse measure of viscosity. High MI implies low viscosity, and low MI means high viscosity. Plastics are shear thinning, which means that their resistance to flow decreases as the shear rate increases. This is due to molecular alignments in the direction of flow and disentanglements.

Viscosity is usually understood to mean Newtonian viscosity, in which case the ratio of shearing stress to the shearing strain is constant. In non-Newtonian behavior, which is the usual case for plastics, the ratio varies with the shearing stress. Such ratios are often called the *apparent viscosities* at the corresponding shearing stresses. Viscosity is measured in terms of flow in Pa·s (P), with water as the base standard (value of 1.0). The higher the number, the less flow. See **fluidity; melt flow; melt strength; molecular weight and melt flow; molecular weight, toughness, and temperature; Reynold's number; test, melt index; viscosity, Newtonian flow; viscosity, non-Newtonian flow.**

viscosity, absolute The ratio of shear stress to shear rate. It is the property of internal resistance of a "fluid" (plastic melt) that opposes the relative motion of adjacent layers. It is the tangential force on unit area of either of two parallel planes at unit distance apart when the space between the planes is filled with the fluid in question and one of the planes moves with unit differential velocity in its own plane. Its unit is the poise (dyne-sec./cm^2). The centipoise (0.01 poise) is often used. Also called *dynamic viscosity.*

viscosity, apparent (AV) The ratio between shear stress and shear rate over a narrow range for a plastic melt. It is a constant for Newtonian materials but a variable for plastics that are non-Newtonian materials. See **dilatant; mathematical equation, cross-; viscosity.**

viscosity, apparent body Body is the apparent viscosity of material, such as paint, varnish, or oil, as assessed subjectively on application of a shearing force by, for example, pouring from a can or stirring. High-AV material is said to be full-bodied or heavy-bodied; low-AV is light-bodied. A false-body describes a full-bodied material that, on agitation, undergoes a marked decrease in AV and then returns to its former condition when left at rest.

viscosity, breaking A petroleum refinery process that is used to lower or break the viscosity of high-viscosity residuum by thermal cracking of molecules at relatively low temperatures. Also known as *vis-breaking.*

viscosity, coefficient The shearing stress that is necessary to induce a unit velocity gradient in a material. See **coefficient of viscosity.**

viscosity, depressant A substance that, when added in a relatively minor amount to a liquid, lowers its viscosity. Such materials are often incorporated in vinyl plastisols to lower their viscosities without increasing plasticizer levels. See **plastisol.**

viscosity, dilute-solution Measured under prescribed conditions, is an indication of the molecular weight of a plastic. See **diluent; molecular weight; solution, dilute.**

viscosity, dynamic See **rheological mechanical spectrometer; viscosity, absolute.**

viscosity, Hagen-Poiseuille law of Common methods of measuring viscosity by amount of flow through the capillary tube make use of this law. See **flow, Poiseuille; pressure flow; rheometer, capillary.**

viscosity, inherent The logarithmic viscosity number that is determined by dividing the natural logarithm of the relative viscosity (sometimes called viscosity ratio) by the concentration in grams per 100 ml of solution.

viscosity, intrinsic For a plastic, the limiting value of an infinite dilution. It is the ratio of the specific viscosity of the plastic solution to its concentration in moles per liter. Also called *limiting viscosity number.*

viscosity, kinematic The absolute or dynamic viscosity divided by the density of the fluid with both at the same temperature.

viscosity, K-value A number calculated from a dilute-solution viscosity measurement of a plastic used to denote degree of polymerization or molecular size. See **polymerization, degree of.**

viscosity, Mooney See **test, Mooney viscosity.**

viscosity, Newtonian flow A flow characteristic where a material (liquid, etc.) flows immediately on application of force and for which the rate of flow is directly proportional to the force applied. It is a flow characteristic that is evidenced by viscosity that is independent of shear rate. Water and thin mineral oils are examples of fluids that possess Newtonian flow. See **flow; melt-flow behavior; rheological material behavior; rheology; shear rate; viscosity, non-Newtonian flow.**

viscosity, Newtonian flow, bingham body A substance that behaves somewhat like a Newtonian fluid in that there is a linear relation between rate of shear and shearing force but it also has a yield value. See **rheology.**

viscosity, non-Newtonian flow Some plastic melts or liquids have abnormal flow response when force is applied. That is, their viscosity is dependent on the rate of shear. They do not have a straight proportional behavior with application of force and rate of flow; when proportional, the behavior has a Newtonian flow. Deviations from this ideal behavior may be of several different types. One type called *apparent viscosity* may not be independent of the rate of shear; it may increase with shear rate (shear thickening or shear dilatancy) or decrease with rate of shear (shear thinning or pseudoplasticity). The latter behavior is usually found with plastic melts and solutions. In general such a dependency of shear stress on shear rate can be expressed as a power law. Another type is where the viscosity may be time dependent, as for materials exhibiting thixotropy or rheopexy. The usual type found with plastic melts and solutions is where the fluid may exhibit elastic effects that are elasticoviscous fluids. Basically flow of a plastic melt is characterized by nonproportionality between shear rate and shear stress. See **flow; melt flow behavior; rheological material behavior; rheology; shear rate; viscometer, Weissenburg effect; viscosity, apparent; viscosity, Newtonian flow; Weissenburg effect.**

viscosity, non-Newtonian flow Ellis model A model describing the flow behavior of a non-Newtonian fluid. The model predicts Newtonian behavior when the viscosity is at zero shear rate. See **flow model.**

viscosity, reaction See **processing, reaction viscosity.**

viscosity, reduced The ratio of the specific viscosity to the concentration. Reduced viscosity is a measure of the specific capacity of the plastic to increase the relative viscosity. The IUPAC term is *viscosity number.* See **liquifier.**

viscosity, relative (RV) The ratio of the absolute solution viscosity (of known concentration) and of the absolute viscosity of the pure solvent at the same temperature. IUPAC uses the term *viscosity ratio.*

viscosity, shear See **CAMPUS database; shear stress.**

viscosity, specific The relative viscosity of a solution of known concentration of the plastic minus one. It is usually determined for a low concentration of plastics, such as 0.5g/100 ml of solution or less.

viscosity, stoke The unit of kinetic viscosity. It is obtained by dividing the melt's absolute viscosity by its density. A centipoise is 0.01 of a stoke. See **poise.**

viscosity susceptibility When not otherwise qualified, the degree of change in viscosity with temperature.

viscosity test See **test, Mooney viscosity.**

viscous A term used more or less exclusively in describing liquids and denoting that they are thick and syrupy or possess poor flow properties. See **Euler equation.**

viscous modulus See **creep modulus, apparent.**

viscous process The best and best-known process for making regenerated cellulose (rayon) is by converting cellulose to the soluble xanthate, which can be spun into fibers and then reconverted to cellulose by treatment with an acid. The process starts with wood pulp in a 17 to 20% caustic soda. See **cellophane; fiber, rayon; xanthate.**

vision correction system A device incorporating NASA image processing technology that enables low-vision sufferers to better accomplish everything from reading to walking to working on a computer. The project founder was Robert Massof, of Johns Hopkins University Hospital. Extensive use is made of the head-mounted battery-operated video display that serves as a real-time electronic telescope. It allows the operator to tune the focus and magnification to perform specific tasks. See **lens, contact.**

vision system inspection See **computer image-processor; inspection, vision-system.**

visual inspection See **inspection, visual; transmission electron microscope.**

vitreous Material that is glassy or glasslike. See **glassy state.**

vitrification See **waste vitrification.**

void An air or gas pocket that has been trapped in the plastic during processing. See **air entrapment; porosity; stress whitening; venting.** Voids in a plastic can be entrapped air or just a vacuum. Voids within or between plastic plies can occur during processing in nonreinforced or reinforced plastics. Depending on the application of parts, such as outdoor weathering, voids can cause a reduction in part performance or interference with transparent property. If voids are undesirable, procedures can be used to reduce or eliminate them, such as applying a vacuum during processing. The experimental determination of the volume of voids is indirect—that is, it is calculated from the measured density of a cured or solid part and the theoretical density of the raw material or compound. See **air entrapment; air-void curve, zero; reinforced plastic void content; specific gravity, apparent; test, nondestructive temperature differential by infrared.**

void, locating See **test, nondestructive ultrasonic.**

volatile Readily vaporizable at relatively low temperatures. A material such as water or alcohol, in a sizing or plastic formulation, is capable of being driven off as vapor at room temperature or slightly higher. It has a measurable vapor pressure that can be a liquid, such as an organic solvent, that continually releases vapors in the air until completely exhausted. Plastics containing volatiles, if not released, can cause bubbles, scarred surfaces, and other defects. See **drying; ignition loss; outgassing; vapor pressure; venting.**

volatile content The percent of volatiles that are driven off as a vapor from a plastic or an impregnated reinforcement during fabrication. See **devolatilization; prepreg volatile content.**

volatile loss Weight loss by vaporization. See **evaporation; volatile loss.**

volatile, non- Not having a measurable vapor pressure.

volatile organic compound (VOC) Volatile organic compound contamination that needs to be removed or reduced below maximum regulation levels. VOCs reduction involves different plastic processing techniques, such as paint systems that use carbon dioxide finishing systems. See **carbon dioxide; coating, electrostatic-spray; dioxin; finish system, reduced solvent; hazard; incineration fume system.**

volatility product A product of the concentrations of two or more molecules or ions that react to form a volatile substance.

volcano Volcanoes provide rich soils, valuable mineral deposits, and geothermal energy. Over geological time, they also recycle earth's hydrosphere and atmosphere. See **atmosphere; filler, mineral.** See **deviation, root-mean-square voltage; electrical volt; reduction potential, standard.**

volume **1.** It is the synonym for capacity or displacement. **2.** One liquid quart is approximately 0.946 liter (L) or 946 cm^3. **3.** A 10 cm × 10 cm × 10 cm cube is one dm^3; also called one liter or 1000 cm^3. See **blow molding, extruder bottle-volume adjustment; calculus; dilatant; electrical-volume resistivity; melting temperature; solid-waste volume reduction; thermodynamic properties.**

volume fraction The fraction of a constituent material based on its volume.

volume, specific **1.** The reciprocal of the material's density. **2.** The volume of a unit weight of a substance in ft^3/lb, m^3/kg, etc. **3.** See **thermal data.**

volumeter An instrument that measures the volume of a known mass of a substance for the purpose of determining its density.

volume-to-weight conversion Multiplying volume (in^3) by specific gravity (s.g.) and dividing by 16.23 will equal weight in grams (g). See **cost per volume of plastic; specific gravity conversion; weight-to-volume conversion.**

volumetric Referring to the measuring of components by volume rather than weight. See **chemical analysis, volumetric; coefficient of expansion; melt flow.**

volume, unit Weight per unit volume.

volume versus weight See **cost per volume of plastic; volume-to-weight conversion.**

vulcanizate The product of vulcanization, such as cross-linking rubber or thermoset plastic elastomer. It is an irreversible transformation from a predominantly "plastic" to predominantly elastic material by vulcanization (chemical curing or cross-linking) using heat, vulcanization agents, or accelerators. See **cross-link; elastomer; elastomeric alloy; extruder liquid-curing-medium; peptizer; plastic, synthetic; thermoplastic vulcanizate; vulcanization, de-;**

vulcanizate backrinding A rupture at the parting line when a vulcanizate (neoprene, etc.) expands when the mold is opened. It occurs when the expansion is concentrated in a small area and the ultimate elongation of the vulcanizate is exceeded. To eliminate the problem requires filling the cavity with just enough stock (volume). Preheating to a temperature close to that of the mold may be more practical.

vulcanizate cross-link A chemical bond that is formed between plastic chains in rubber as a result of vulcanization.

vulcanization A process in which rubber or plastic undergoes a change in its chemical structure brought about by the irreversible process of reacting the materials with sulfur and/or other suitable agents. This cross-linking action result in property changes such as decreased plastic flow, reduced surface tackiness, increased elasticity, much greater tensile strength, and considerably less solubility. Similar cross-linking action occurs with thermoset plastics. See **adhesive, room-temperature cure; catalyst, benzoyl peroxide; extruder, Ballatini process; extruder wire and cable process, continuous vulcanization; factice; litharge; masticate; tensile green strength; thermoset plastic; vulcanization, de-.**

vulcanization, de- The term is used to describe the softening of a vulcanizate caused by heat and chemical additives during reclaiming or recycling. Technically a misnomer since vulcanization is irreversible (thermoset action). See **thermoset plastic; vulcanization.**

vulcanization, dynamic A process in which the elastomer phase is cured during mixing of the material rather than just mechanically blended.

vulcanization scorch Premature vulcanization of a rubber compound.

vulcanize To subject a material to vulcanization. See **litharge.**

vulcanized elastomer Producing a material with good elastomer properties involves the formation of chemical cross-links between high-molecular-weight linear molecules. The starting material is of the noncrystallizing type, and its glass transition temperature is well below room temperature to ensure a rubbery behavior. This formation of chemical cross-linking is commonly referred to as *vulcanization* or *curing*. See **cross-linking; elastomeric alloy; factice; glass transition temperature; thermoplastic elastomer.**

vulcanized fiber A processed regenerated cellulose fiber or viscose rayon that was patented in 1871. It is between the natural plastics, such as gutta percha and shellac, and the synthetics, such as nylon and phenolics. This material was once popular but now is almost obsolete. See **fiber.**

vulcanized fiber fish paper Electrical insulation in a thin cross-section.

vulcanizing agent A compounding material that produces cross-linking in rubbers or elastomers.

vulcanizing system The vulcanizing agent and, as required, accelerators, activators, and retarders that are used to produce the desired degree of vulcanization characteristics.

W

Wacker process A process for the oxidation of ethylene to acetaldehyde by oxygen in the presence of palladium chloride and cupric chloride. See **acetaldehyde; ethylene; oxidation.**
wadding See **fiber wadding.**
wafer A thin disclike section of a semiconductor crystal that is used for the fabrication of semiconductor devices.
warehousing The storing of raw materials, additives, auxiliary equipment, spare parts, molds, dies, tools, and processed plastic parts. Various handling and storage procedures are used, such as the unit warehouse, which makes use of pallets, cages, and similar equipment. It employs a certain organizational scheme for integrating order-picking and transportation. The system is perfected by integration of the inward and outward flow (input-output matrix) of goods, the factory administration, process control, and quality control. See **bulk storage; container lid, stacking/capper; cost, demurrage; fabricating, asynchronous; inventory; material handling; production data acquisition; processing, inline; quality control; storage.**
warmware See **computer warmware.**
warpage The dimensional distortion in a part after processing. The most common cause is variation in shrinkage of the part. The major processing factors involved are flow orientation, area shrinkage, and differential cooling. See **shrinkage; tolerance allowance; yarn warp.**
warp face See **fabric warp face.**
warranty See **legal matter: warranty.**
waste Waste considerations include reduction at source, reducing volume, reusing and recycling materials, collecting and separating (material recycling, chemical recycling, etc.), incineration, and landfill. Each has its advantages and disadvantages, particularly when considering efficiency and costs. Recovery involves generic material reclamation, mixed plastics waste recycling, energy recovery, and recover as monomers (hydrolysis, pyrolysis, hydro cracking, etc.). All kinds of data on contributors exist with a probable estimate based on percent by weight and percent by volume (wt%/vol%). For municipal solid waste landfill there are paper 37/40, yard trimmings 18/18, metal 10/2, glass 9/3, food 8/8, plastic 7/12, and others 11/13. Also called *refuse.* See **aeration; bacteria, aerobic; biodegradable waste; chemical reclamation; communition; compost; decomposition; ecology; energy efficiency; geomembrane; geotextile; hydrolysis; incineration; landfill and degradation; osmosis, reverse; plastic and lumber; plastic and pollution; polylactic plastic; pyrolysis; recycling; sludge; starch degradable; waste, pressure cooking; waste, solid.**

Every Sunday more than 500,000 trees are used to produce the 88wt% of newspapers that are never recycled. Americans throw away enough glass bottles and jars to fill the 1,350 ft (412 m) twin towers of the New York's World Trade Center every two weeks. Americans use 2.5 million plastic bottles every hour. Americans spend more on food packaging than U.S. farmers earn for the food they grow. Excess packaging costs the consumer twice: first when purchased and then when disposed of. Thus $1 of every $10 spent on food is actually paid for the packaging, which then becomes one-third of the solid-waste stream. American consumers and industry throw away enough aluminum to rebuild the United States's entire commercial airfleet every three weeks. Americans throw away enough office and writing paper annually to build a wall 12 ft (3.7 m) high from Los Angeles to New York City. Americans throw away enough iron and steel to continuously supply all the U.S. automobile makers. See **environment and public opinion; plastic myths and facts; recycling.**
waste, plastic-bag The Environmental Protection Agency has reported that plastic bags and sacks represent less than 1 percent by volume of all garbage sent to landfills. See **packaging, grocery-bag.**
waste and plastic packaging Plastic packaging contributes to the safety of consumers by preventing spoilage, providing tamper-control seals, containing infection, and so on. It is lightweight and shatterproof. Plastic packaging delivers more than 60% of all the goods that enter U.S. homes and yet accounts for 20% of all the packaging waste discarded. If all packaging were replaced with other materials, the result could be as follows: weight of waste would increase 404%, volume of waste 256%, use of energy 201%, and cost of packaging 212%. See **packaging, pouch heat-sealed wraps and reusable containers.**
waste biostabilizer A machine that converts solid waste into compost by granulating and aeration.
waste compaction For recycling mixed or contaminated plastic waste, one can either separate different ingredients or compatibilize the mixture so that it results in useful properties. See **compaction.**
waste conversion, chemical A technique that includes hydrolyzing (PET, etc.) waste and different chemical depolymerization processes. See **chemical reclamation.**
waste, effluent Any gas or liquid emerging from a pipe or similar outlet. It usually refers to waste products from plants and buildings as stack gases and liquid mix. It also refers to exhaust from fuel energy powered machines (automobiles, buses, trucks, etc.).
waste, hazardous In general, all wastes that are primarily industrial in origin and have corrosive, ignitable, toxic

or reactive characteristics, or are a regulated waste because of a specific industrial process. Worldwide, most hazardous waste is recycled, treated, or disposed of on the property where it was created or at commercial off-site hazardous-waste facilities. Various types of regulations exist worldwide, such as U.S. Consumer Product Safety Act, U.S. Federal Register 29 CFR 1910.1200, U.S. FDA Certifications, U.S. EPA Emission Requirements, U.S. OSHA Workplace Guidelines, ISO-9000, ECO-Audit (European), and British Standard 7750. See **adulterant; dust, industrial; geomembrane; geotextile; hazard; legal matter: Consumer Product Safety Act; risk, acceptable; safety; styrene monomer emission; toxicity.**

waste, industrial Waste that is generated in industrial or manufacturing operations. It is categorized as scrap, which can be recycled at a profit, or waste, which cannot be recycled or reclaimed but can be incinerated at a profit. See **material, recovered; osmosis, reverse.**

waste, invisible Dust, moisture, or loose fibers that are carried away by the atmosphere. See **atmosphere; atmosphere, dry deposition; pollution, air.**

waste, municipal solid Residential and light commercial solid waste that is collected from a selected municipality or geographic area. It includes sewage sludge as distinguished from air pollution or wastewater.

waste, plastic See **commingled plastic; plastics cradle-to-grave; plastic material; recycled plastic; waste compaction.**

waste, postconsumer Any material that has been distributed to the consumer. After use it is subject to landfill or recycling. See **material, recovered; preconsumer.**

waste, pressure cooking In the search for ways to safely and totally destroy megatons of discarded by-products from different sources worldwide, a promising technology is emerging called *supercritical water oxidation.* With SCWO, oily material generally does not dissolve in water. It floats, and inorganic salts tend to dissolve very easily. But when taken up to its critical point (375°C, 3,200 psi), organic materials dissolve. Thus organic wastes dissolve above the critical point, which are not particularly high by industrial standards, so that the action results in pressure, cooking materials. Once the organic matter is dissolved and oxygen added, a combustion reaction takes place in the water stream. Harmful products (CO_2, NH_4, NO, etc.) or odors are not released as vapors but are contained in the water stream.

waste rasp A machine that grinds waste into a manageable material and helps prevent odors. See **odor.**

waste, recycling See **chemical reclamation; recycling method, economic evaluation of; recycling waste; waste, pressure cooking.**

waste, refuse-derived fuel See **energy reclamation; refuse-derived fuel.**

waste separation, sink-floatation A method that involves placing plastics as well as other materials with different densities in a water tank and allowing them to separate according to their density.

waste, solid Materials that are discarded after use, as distinguished from air pollution or waste water. It includes sewage sludge. Household waste is known as solid waste. See **bulk factor; communition; landfill and degradation; sludge; solid-waste volume reduction; stabilization; vinyl composition tile.**

waste, solid commercial Wastes produced during wholesale, retail, or service business operations. It is often collected by private contractors rather than by public agencies.

waste, solid, council The Council for Solid Waste Solution (CSWS) of SPI is an organization that provides help and solutions to the solid waste situation.

waste, solid food The food industry—from the farm, through shipment and storage, to the end user—produces enormous solid waste that is used in landfills and incineration. With the help of plastics (films, containers, etc.) food waste is reduced. See **packaging, food.**

waste, solid, management The systematic management of solid waste from the point of generation to final disposal. It can include source reduction, collection, storage, transfer, recycling, recovery, incineration, and landfill.

waste, solid urban Solid-waste material that includes garbage, glass, plastic, and metal. It does not include air pollution or waste-water materials.

waste, source reduction of Changing a process or product so that less waste material is generated. Source reduction is to garbage what preventive medicine is to health or preventive maintenance is to equipment. This action eliminates or significantly reduces a problem before it can cause problems. See **design packaging.**

waste-to-energy The recovery or generation of energy through incineration of waste. See **energy reclamation.**

waste vitrification A thermal process that involves the melting of ash residues from municipal waste-to-energy facilities and other combustion systems. The process takes place in a sealed electric furnace.

wastewater treatment See **geotextile; water pollution.**

water (H_2O) A clear, colorless, tasteless, odorless liquid that is essential for animal and plant life. It is an excellent solvent for many substances with a melting point of 0°C (32°F) and a boiling point of 100°C (212°F). It is important in the fabrication of most plastic products. It also influences the behavior of certain fabricated plastic products. Also called *hydrogen dioxide.* See **aqua; desiccant; drying; hydrological cycle; hydrolysis; hydrophilic; hydrophobic; hygrothermal effect; insoluble; moisture; plastic, hygroscopic; specific gravity.**

water absorption The ratio of the weight of water absorbed by a material to the weight of the dry material under specific conditions, such as temperature and humidity. See **absorption; moisture absorption; shell flour; test, water absorption.**

water adsorption The pickup of water vapor from air only on the surface of the material. See **adsorption; water pollution.**

water affinity See **hydrophilic.**

water and gel See **aerogel.**

water-aqueous Consisting of water or concerned with water. See **coating, water-borne system.**

water beading The formation of discrete water droplets on a polished surface.
water boiling point See **boiling point.**
waterborne coating See **coating, water-borne system.**
water, brackish Water that is lower in salinity than normal salt water and higher in salinity than freshwater, ranging from 0.5 to 30 parts salt per 1,000 parts water. It is located between sea water and fresh water. See **water, desalination of.**
water break The appearance of a discontinuous film of water on a surface that signifies nonuniform wetting and usually is associated with a surface contamination.
water brine **1.** Water having more than approximately 30,000 mg/L of dissolved matter. **2.** Any solution of sodium chloride and water that usually contains other salts. See **water, desalination of.**
water channel See **barrel cooling; mold water channel.**
water conservation and plastic See **plastic and water conservation.**
water condensation See **hygrometer.**
water contamination See **pipe, deteriorating.**
water content, air void See **air-void curve, zero.**
water, desalination of Any of several processes for removing dissolved mineral salts from ocean water, brackish water, or other brines. Effective methods for desalination of seawater or brackish water include solar distillation, electrodialysis, reverse osmosis, and flash distillation. See **environment and ocean; osmosis, reverse; vinyl seagoing bag; water, brackish.**
water flow meter See **mold-cooling flow meter.**
water-glass See **metal impregnation; sodium silicate.**
water, hard Water that contains certain salts, such as calcium and magnesium, which form insoluble deposits in devices such as water cooling of molds. Also called *salt water.* See **water, magnetic.** Hard water that does not contain bicarbonate ions is said to have permanent hardness. Hard water that contains bicarbonate ions is said to have temporary hardness.
water, hydrophobic See **lyophobic.**
waterlike/water-fearing See **hydrophilic; hydrophobic.**
water, magnetic Magnetic water conditioning systems are designed to improve the efficiency of existing water softeners in chillers and other equipment by reducing scale formation. Improved heat transfer in equipment, such as molds, that comes in contact with water is a major benefit. This technology has been used in other industries since the 1940s. Nothing is taken out of the water; nothing changes except that the solution is kept so there are no hard crystal formations. Magnetic fields align molecular particles of calcium carbonate in water so they cannot form the hard scale that adheres to the hot surfaces. The molecules are retained in solution and pass harmlessly through the water system. See **chiller; mold cooling; water, hard; water softening.**
water of hydration Water is in a definite amount and attached to a compound to form a hydrate. It can be removed, as by heating (thermal decomposition), without altering the composition of the compound. Also called *water of crystallization.* See **thermal decomposition.**
water of saturation Water supporting colloidal particles in a slip (slurry). See **saturation; water saturation.**
water property General information follows. One gallon of water weighs 8.3356 lb at 62°F (air free weighed in a vacuum). One gallon of water occupies 231 $in.^3$ or 0.13368 ft^3. One ft^3 equals 7.4805 gallons. One in^3 weighs 0.576 oz. The maximum density of water occurs at 39.1°F. Freezing point at sea level occurs at 32°F. One ft^3 at 39.1°F exerts 0.4335 psi. Boiling water at sea level occurs at 212°F. See **specific gravity.**
waterproofing The treatment of a surface or structure to prevent the passage of liquid water under hydrostatic, dynamic, or static pressure. See **aluminum stearate; porous, micro-.**
water purification See **geomembrane; ion exchange, plastic.**
water, recycle See **hydrological cycle.**
water repellent A material, or treatment, for surfaces to provide resistance to penetration of water.
water resistance **1.** The measured ability of a substance to retard both penetration and wetting by water in liquid form. **2.** The ability of a part to resist deformation or change in characteristic, such as color, with immersion in water or exposure to water. See **water absorption.**
water, salt See **marine applications for plastics.**
water saturation **1.** A solid absorbent that holds the maximum possible amount of water under specific conditions. See **saturation; water of saturation.** **2.** A liquid solution in which additional water will cause the appearance of a second liquid phase. **3.** A gas that is at or just under its dew point because of its water content.
water seepage, concrete See **plastic-concrete composite.**
water, soft See **water, hard.**
water softening Removal of scale-forming calcium and magnesium ions from hard water, or replacing them by the more soluble sodium ions. This can be done by chemicals or ion exchange. See **mold cooling; plastic, ion exchange; scale; water, magnetic; zeolite.**
water soluble plastic See **plastic, water-soluble.**
water solution See **alkali.**
water surface tension See **detergent.**
water swell The expansion of material volume as a result of water absorption. See **absorption.**
water thickener See **polyvinyl pyrroldone plastic.**
water transfer venting See **mold venting, water-transfer.**
water treeing See **cable insulation water treeing.**
water-vapor diffusion The process by which water vapor spreads or moves through permeable material because of a difference in water-vapor pressure. See **diffusion.**
water vapor resistance The measured ability to retard penetration and permeation by water vapor.
water vapor resistivity The steady vapor-pressure difference that induces unit-time rate of vapor flow through

a unit area and a unit thickness of a flat material, or construction that acts like a homogeneous body, for specific conditions of temperature and relative humidity at each surface. See **barrier.**

water vapor retarder A material, such as a plastic barrier, or system that adequately impedes the transmission of water vapor under specific conditions. Also called *water-vapor barrier.* See **barrier plastic.**

water vapor transmission (WVT) The rate of water-vapor flow, under steady specified conditions, through a unit area of material, between its two parallel surfaces. The metric unit of measurement is 1g/24 h m^2. Perm is a unit of measurement of water-vapor permanence where a metric perm is 1 g/24 h m^2 mm Hg, or of 1 g/h ft^2 in Hg. See **barrier plastic; membrane; permeability; test, permeability; test, water-vapor transmission rate.**

waterway and marine standard See **bottle standard reference material.**

water wettable See **hydrophilic.**

water, white Having the appearance and clarity of water.

watery suspension See **slurry.**

watt See **electrical watt.**

wave **1.** An optical effect that is due to uneven transparent material distribution. **2.** A disturbance is propagated in a medium in such a manner that at any point in the medium the amplitude is a function of time, while at any instant the displacement at a point is a function of the position of the point. It is a regular vibration or oscillating vibration by which energy is transferred through space or some other media. Also called *striae.* See **optical property; vibration.**

wave front A continuous surface drawn through the most forward points in a wave disturbance that have the same phase.

wavelength **1.** The distance measured along the line of propagation of a wave, between two points that are in phase on adjacent waves. **2.** A measure of the nature of incident electromagnetic radiation. See **infrared; radiation, monochromatic.**

wavelength, standard Accurately measured lengths of waves emitted by specified light sources for the purpose of obtaining the wavelengths in other spectra by interpolating between the standards.

wave number The number of waves per unit length.

waviness A wavelike variation from a perfect surface. It is generally much wider in spacing and higher amplitude than surface roughness. See **kink; surface finish.**

waviness surface See **plastic, low-profile.**

wax Any substance that physically resembles beeswax. It is a dull, crystalline-solid plastic when warm. Some waxes are composed of a mixture of esters, cerotic acid, and hydrocarbons. Other waxes are made from various animals, vegetables, minerals, or synthetic sources. Waxes differ from fats in being less greasy, harder, more polishable by rubbing, and containing esters of higher fatty acids and higher alcohols, free higher acids or higher alcohols, or saturated hydrocarbons. Waxes are used with plastics as a mold-release agent and as an additive to improve processing and/or performance. See **beeswax; carnauba wax; finishing, ashing and lapping; paraffin wax.**

wax, soluble core Wax can be used in certain soluble-core moldings instead of using the usual eutectic material. See **eutectic mixture; reinforced plastic molding, lost-wax; soluble core molding; wax.**

wear The cumulative and integrative action of all the deleterious mechanical influences that are encountered in use and that tend to impair a material's serviceability. For example, it is the damage to a solid surface, generally involving progressive loss of material due to relative motion between that surface and a contacting substance. See **ablation; abrasion; abrasion resistance; bearing; cavitation erosion; frettage; galling; mold-cavity coating; rain; screw wear; silicone processing aid; spalling.**

weatherability The ability of a plastic to withstand the deleterious or degradation effects of ultraviolet radiation, thermal effects (high to low temperature changes), moisture, air contamination, and other atmospheric conditions. The two major testing approaches are natural outdoor conditions and accelerated laboratory exposures that simulate outdoor conditions. Natural-exposure methods include both direct and under-glass exposure. Since most actual weather conditions are not uniform or repeatable, the usual approach is to conduct any test that is more severe than what is expected. In the United States outdoor tests are usually conducted in a hot, dry climate such as in the Arizona desert and also in a hot, wet climate such as in Florida. In all areas, controlled conditions are used, such as the type and geometry of test specimens, elimination of contact with vegetation, no shading, and no dust blowing, and time periods of exposure that range for days, weeks, months, and years. Even though most exposure test stands are conducted facing the equator at 5 to 45° with most at 45° from the horizontal, many are adjustable to accommodate different requirements. A 0° (horizontal) is used for roofing material. For drainage and dirt wash-off rains a 5° is used. There is also accelerated outdoor exposure, such as using a Fresnel-reflector test machine that follows the sun so that sunlight is always concentrated on the test specimens. A high confidence level cannot be established based on test results since weather conditions constantly change, but tests provide guidelines for what could happen, particularly if very extreme conditions were used such as very long time of exposure. See **aging, artificial; atmosphere; degradation; design and weathering; Fresnel lens.**

weather condition, factual Outdoor weathering provides combinations of different factors that range from natural climatic to industrial environmental conditions. In the arctic, temperatures can range from −40 to −70°C; the desert is from +60 to −10°C with surfaces reaching 75°C and relative humidity from 5 to 10% inland; and tropical areas range from 20 to 52°C with surfaces reaching 70°C and relative humidity in excess of 90% at night. Solar radiation can cause stresses from cross-linking reactions; humidity can cause swelling, leaching, and fatigue stresses;

and temperature can cause thermal degradation, thermal stresses, thermal fatigue stresses, evaporation of unreacted plastics, and loss of volatile additives. Properties of plastics affected include strength, dimensions and mass, surface appearance, electrical properties, thermal conductivity, and bond integrity. Thus, it is important to use the required plastic that is properly processed to counter these types of weather problems. Some plastics can survive the weather conditions: Some plastics have met performance requirements for over a half century in outdoor use worldwide. See **temperature.**

weather condition, normal The range (actual and anticipated) of environmental conditions (rain, temperature, pollution, etc.) that typically occur in a local climatic region over several years. See **raindrop.**

weathering, artificial The accelerated testing of plastics to determine their changes in properties. It is usually carried out over a short period of time. See **aging, artificial; weatherability.**

weatherometer An instrument that subjects parts to accelerated weathering conditions using an ultraviolet source and water spray. This is one of many different performing instruments that are used to evaluate performance under different simulated weather conditions.

weatherproofing agent See **carbon black; photo-oxidation; zinc formate.**

weave See **fabric, woven.**

web A continuous sheet or film. In flat extrusion, for example, it is the extrudate leaving the sheet die. In extrusion blown film, it is the film leaving the collapsing rolls. In thermoforming, it is the continuous-roll stock that is fed to the thermoformer. In web coating, it is the substrate on which the coating is applied. See **calender; extruder-blown film; extruder flat film; extruder sheet; substrate.** It can refer to a continuous fabric (also paper, thin metal foil, etc.) as contrasted to the same material cut into sheets. See **fabric, nonwoven; fabric, woven.**

web coating See **coating, spread; extruder coating and lamination.**

web guide A device for positioning, centering or controlling both edges of any material that is used in different processing lines, such as calendering, extrusion, and fabric impregnation.

website See **Appendix G. Websites on Plastics.**

web tension control See **extruder-web tension control; extruder-web tension control, slipping and tearing.**

weeping A slow leakage that is manifest by the appearance of water, or other product such as a plasticizer, on a surface.

weft The threads of a woven structure that can run across the fabric from selvedge to selvedge at right angles to the warp threads. See **fabric; yarn fill.**

weftless Applied to a tire cord fabric without any weft or cross threads. The individual cords are spaced out, passed into a plastic adhesive, dried, and coated with rubber compound by calendering.

weight In commercial and everyday use, *weight* nearly always means mass. In science and technology, the term *weight* usually means the force that, if applied to the body, would give it an acceleration equal to the local acceleration of free fall on the surface of the earth; it is the force that gravity exerts on a body. See **decimal number system; density; load; mass; specific gravity; tare.**

weight, areal See **reinforced-plastic weight, areal.**

weight, equivalent See **molecular weight.**

weight feeder See **feeder, gravity.**

weight, material Materials are weighed in g/cm^3 (lb/ft.^{3}). For example, aluminum is 2.68 (167), copper/bronze 8.8 (549), plastic 0.9 to 1.2 (56 to 75), steel 7.9 (493), wood maple 0.45 (28), and zinc 6.7 (418).

weight, specific The weight per unit volume of a substance.

weight-to-volume conversion Divide weight (g) by the plastic's specific gravity (s.g.) times 16.36 equals volume in in^3. See **cost per volume of plastic; volume-to-weight conversion.**

weight, unit The weight per unit volume.

weir See **extruder pipe, cooling-tank weir.**

Weissenburg effect The tendency of a material to flow inward. It is the change in normal stresses on a non-Newtonian, elastic material that causes the material to rise on the inner cylinder of two concentric, rotating cylinders, despite the centrifugal force. See **stress; viscometer, Weissenburg effect; viscosity, non-Newtonian flow.**

weld factor The ratio of weld strength to strength outside the welded zone, typically determined by tensile specimen tests.

welding Joining thermoplastic parts by one of several heat-softening processes. Various techniques are used to make permanent bonds between materials that can meet different requirements, such as shapes, thickness, appearance, bond strength, capability of the different materials being bonded, hermetic seal, or effect of additives or fillers used in the plastics. Once a process is being used, if the compound additives or fillers are changed or added, bond performance can change or even fail; with glass fiber fillers, which do not melt, welding can fail. See **adhesive; automotive intake manifold; bonding; design disassembly; fit; joining-and-bonding method; sealing, ultrasonic; staking; ultrasonic fabrication.** Weldability is influenced by factors such as plastic composition and moisture content. Certain fillers, particularly in high concentrations, that do not melt can cause parts to have weak or disastrous joints after long and even short service. Lubricating agents, release agents, and glass fibers are examples of additives and fillers that interfere with welding ability.

welding amplitude The amplitude used in a welding process. In a vibratory motion such as in a vibration or ultrasonic welding, it is the distance from the equilibrium position to the point of maximum displacement. Variations occur with the welding techniques used and with the geometry and composition of the parts.

welding, dielectric See **heat, dielectric.**

welding, electrofusion A process that is commonly used in joining polyethylene plastic pipe. Joints obtained are fluid tight and capable of withstanding heavy loads for over 50 years. Electricity is applied to a heating element surrounded by two thermoplastic materials that are to be joined, such as ends of extruded pipe. The heat produced causes the TPs to melt and flow together, forming a weld.

welding, electromagnetic-induction A type of welding that uses a radio-frequency magnetic field to excite fine, magnetically sensitive particles, either metallic or ceramic. The particles are usually imbedded in a preform, filament ribbon, coextruded film, adhesive, or molding compound. Often an extra part, such as a preform, contains the magnetically active particles. The preform is placed at the joint interface and exposed to an electromagnetic field. Electromagnetically induced heat is conducted from the particles through the preform and to the part joint as the parts are pressed together.

welding, electron-beam A welding process wherein coalescence is produced by the heat obtained from a concentrated beam that is composed primarily of high-velocity electrons impinging on the surfaces to be bonded.

welding, extrusion See **extruder welding.**

welding, forced bossed The process starts with insert molding. A tapered plastic pin is molded into one of the parts, and a mating boss is molded into the other. The parts are positioned in fixtures and forced together at very high speeds. Frictional heat melts the thermoplastics on the mating surfaces, welding the two parts together. Bell Laboratories owns U.S. patent 4,997,500, 1991 for this process. See **insert molding.**

welding, friction A friction provides the heat necessary to melt the thermoplastic parts at the joint interface. Various methods are used, such as spin welding and vibration welding. See **friction; welding, spin.**

welding, fusion Any of various methods of welding or bonding plastics where the joint line is melted by means of a hot tool. See **adhesive, electromagnetic; fusion; joining, butt.**

welding heat-affected zone In welding, the region of the part that is affected by the heat that is used to melt the joining surfaces. The microstructure of the heat-affected zone is an important determinant of the mechanical strength of the weld.

welding, hot-gas A method for joining thermoplastics in which the parts are softened by hot gas, usually air, from a welding torch and joined together at the softened points. A filler rod composed of the same material as the part can be used to fill and compensate for any gap that may exist between the parts. Also called *hot-air welding.*

welding, hot-tool A method of joining thermoplastic parts in which a hot plate or hot tool is used to provide heat to melt the joining surfaces. The tool is then removed, and parts are pressed together. While in the molten state, molecular diffusion across the joint interface occurs, and a homogeneous, permanent bond is formed after the parts are allowed to cool. A hot plate is used for flat surfaces, and a hot tool in the shape of the joint for irregularly shaped surfaces. PTFE can be coated on the tool to eliminate or reduce sticking. Also called *fusion bonding, hot plate, heat sealing, hot-shoe welding,* or *butt fusion.* See **polytetrafluoroethylene plastic.**

welding, hot-tool, noncontact A form of heated-tool welding in which parts are placed near the hot tool but not in direct contact with it. Heat is transferred to the part surfaces by radiation and convection. The hot tool is removed when melting occurs, and parts are then pressed together for cooling and solidification. It is used for high-temperature plastics when high melting temperatures prohibit the use of nonstick coatings on the hot tool surface.

welding, induction A type of welding that uses induction heating from high radio-frequency alternating current to magnetically excite ferromagnetic particles (stainless steel or iron) embedded in a bonding agent (with a thermoplastic or adhesive matrix) placed at the joint interface of the two parts being welded. The heat released is used to melt and fuse the TPs, to heat hot-melt adhesive, or to provide rapid adhesive cures for thermoset plastics. Also called *magnetic induction welding* or *electromagnetic* (EMA) *welding.* See **heating, induction.**

welding, infrared (IR) A welding technique in which IR radiation is used to heat the surfaces of thermoplastic parts to their melting temperature. Flow of molten material across the joint interface allows a molecular diffusion and weld formation after cooling. IR pertains to the region of the electromagnetic spectrum between visible light and radar (wavelengths 1 to 15 πm). See **infrared.**

welding, infrared, through transmission A welding technique in which IR radiation is transmitted through a part composed of a plastic that does not absorb IR energy to the other part or composed of a plastic that does absorb IR energy at the weld interface. Heat builds up in the absorbing plastic and is transferred to the nonabsorbing plastic through conduction, causing the desired melting of both plastics at the weld interface. The final action is cooling the weld line.

welding, jig The heat welding between suitable jigs. The necessary heat is often introduced to the plastics by applying a RF field and using the jigs as electrodes. Also called *jet welding.*

welding, laser beam A joining method for thermoplastics in which a high-intensity laser beam is used to generate heat at the part surfaces, causing the TP to go above its melt temperature and coalesce on cooling.

welding, microwave A welding technique in which high-frequency electromagnetic radiation, usually 2 to 10 GHz, is used to heat a susceptor material placed at the joint interface. Heat conduction from the susceptor to the joint interface will melt the thermoplastic parts. The molten plastic diffuses together, forming a weld after cooling. Polyaniline doped with an aqueous acid such as HCl is used as a susceptor.

welding process economic guide Information about various welding processes follows:

	Equipment Cost	Tooling Cost	Typical Output Rates	Normal Economic Production Quantities	General Remarks
Hot gas	Very high	Low (holding fixture only)	0.3 to 1.5 m (12 to 60 in) of weld seam per minute	Very low	Manual operation
Hot-plate	Moderately low to high	Moderate to high	About 120 parts/h/fixture cavity	Medium to high	Setup time 1 h or less
Induction	Low to moderate	Low	About 900 parts/h, manually loaded	High	Setup time 1 h or less
Spin	Moderate	Moderate	About 640 parts/h, manually loaded	High	Setup time ½ h, mechanization possible
Ultrasonic	Moderately low to high	Moderate to high	About 1,000 parts/h, manually loaded	High	Automatic operation desired
Vibration	Moderate	Moderate	About 240 parts/h from single cavity, manually loaded	Medium to high	Setup time 10 min, multiple cavities and mechanized loading possible

welding, radio-frequency (r-f) Thermoplastics use a radio-frequency electromagnetic source (13 to 100 MHz) to attain the necessary frequency. The r-f field is usually applied with a metal die in the shape of the joint, causing an increase in molecular motion in the region of the joint. The result is the generation of heat at the joint followed by cooling action. It is commonly used for sealing polar plastic sheets and films. Also called *high-frequency welding* or *heat sealing*.

welding, resistance A welding technique in which heat is generated by application of an electric current to a conductive heating element or implant that is placed at the joint interface. Heat is applied through joule heating. The conductive heating element is usually stainless steel or carbon-fiber prepreg and remains in the joint after welding. Thermoplastics at the joint interface melt and fuse, forming a weld. Thermoset reinforced plastics or composites and metals require a TP interlayer for bonding. Also called *resistance implant welding*.

welding, seam Forming a welded seam in thermoplastics. The material is welded by the application of rollers as in continuous welding or by the progressive application of pressure as in jig or stitch welding. The material may be heated by means of a radio-frequency field or by contact with heated rollers or jigs.

welding, shear joint See **welding, ultrasonic, shear joint.**

welding, solvent See **adhesive, solvent; plasma arc treatment.**

welding, spin A method for joining cylindrical thermoplastics parts. Frictional heat develops as one-part spins against the other stationary part, resulting in melting at the joint interface. Spinning is then stopped, and the parts are held together under pressure until cooled. Typical cycles are 1 to 2 s. High-speed vibrators can be used to feed parts into the welding operation. Also called *friction welding* or *rotational welding*. See **welding, friction; welding, vibration.**

welding, spot The localized fusion bonding of two adjacent plastic parts. To be most effective, it is used where two parallel and flat surfaces meet.

welding, stitch A method of welding thermoplastics using a device similar to a sewing machine but fitted with two electrodes that weld the plastic progressively. The electrodes are fed from a RF generator.

welding, tack An initial and brief weld, such as spot or buttonlike welds, that holds parts of a weldment in proper alignment until the final complete weld is performed.

welding, thermoband A variation of the hot-plate welding method. A metallic tape acting as an electrical resistance element is adhered to the material to be welded. Low voltage is applied to heat the material to its softening point so that the weld forms.

welding, ultrasonic The most widely used welding method for thermoplastics in which energy at ultimate frequencies (20 to 40 kHz; beyond the range of human hearing) is used to produce low-amplitude mechanical vibrations. The vibratory pressure at the joint interface produces frictional heat that melts the parts, allowing them to flow together and bond. Parts may require the use of an energy director to concentrate ultrasonic energy. High-quality welds are easier to obtain with amorphous than crystalline plastics. Electrical energy is changed to ultrasonic vibrations by means of either a magnetostrictive or piezoelectric transducer. See **piezoelectric effect; transducer, magnetostrictive; ultrasonic wave.**

welding, ultrasonic booster In ultrasonic welding, a mechanical transformer used to increase or decrease the amplitude of the horn.

welding, ultrasonic far and near field The distance that ultrasonic energy is transmitted from the horn to the joint interface. Far-field welding occurs when the joint is more than 0.25 in. (6.4 mm) from the point at which the horn contacts the part. Near-field welding occurs when it is equal or less than this distance.

welding, ultrasonic gain In ultrasonic welding, the ratio of output amplitude to input amplitude of a horn or booster.
welding, ultrasonic horn A tool that is used for transmitting energy and pressure. Each horn is designed to fit a certain contact area and tuned to specific amplitudes to efficiently perform the welding operation.
welding, ultrasonic, nodal point The point or points in a booster or horn where little or no linear motion occurs.
welding, ultrasonic scan A continuous, high-speed ultrasonic assembly technique that is used when at least one of the parts to be joined is perfectly flat.
welding, ultrasonic, shear joint An ultrasonic welding joint design where the welding action is parallel to each part surface. See **shear joint.**
welding, ultrasonic spot An ultrasonic welding method in which two parts are joined at localized points.
welding, vibration A method for joining thermoplastics with high-strength bonds in which frictional heat is generated by rubbing the two parts together in a linear or angular motion. This action can be accomplished in a short time of 8 to 15 s. After the heat melts the two materials at the joint interface, vibration action stops and the parts are pressed together. After cooling, the bond is completed. The vibratory motion is a low-frequency (120 to 240 Hz), high-amplitude (0.25 to 0.50 mm or 0.10 to 0.2 in.) of linear displacement, reciprocal motion; a rotary motion is used for circular parts. Different-size parts are used. It is particularly suited for large parts or irregular joint surfaces. Also called *friction welding.*
weld line A mark or line when two melt-flow fronts meet during the filling of an injection mold. This action can also occur during extrusion through a die. Also called *weld mark, flow line,* or *striae.* See **blow molding, extruder cut-off; die line; die spider line; extruder melt-flow oscillation; injection molding melt-flow oscillation; meld line; melt vibration; molding weld-line overflow tab.**
well See **molding cold slug; mold well.**
wet abrasive See **cleaning, abrasion.**
wet ashing The conversion of an organic plastic compound into ash (decomposition) by treating the compound with nitric or sulfuric acid. See **finishing, ashing and lapping.**
wet felting Forming a fibrous simple to a complex-shaped mat from a water suspension. See **preform process, water slurry.**
wet installation See **joining, wet-installation.**
wet lay-up molding See **reinforced plastic lay-up, wet.**
wet-out See **reinforced plastic wet-out.**
wet process, nonwoven See **fabric nonwoven mechanical.**
wet spinning See **fiber processing, spinning.**
wet stretching See **orientation, wet-stretching.**
wet system See **reinforced plastic wet system.**
wettability The ability of any surface to be wetted when in contact with a liquid. See **test, aluminum.**
wetted Pertaining to material that has accepted water or other liquid, either on its surface or within its pore structure. It is the ability of any surface to be wetted when in contact with a liquid—that is, the surface tension of the liquid is reduced so that the liquid spreads over the surface with ease. Also called *wetting.*
wetting agent A substance that is capable of lowering the surface tension of liquids, facilitating the wetting of solid surfaces with good bonding taking place, and facilitating the penetration of liquids into capillaries. It is a phenomenon involving a solid and liquid in such intimate contact that the adhesive force between the two phases is greater than the cohesive forces within the liquid. Thus, a solid is wet and, on being removed from the liquid bath, will have a thin continuous layer of liquid adhering to it. See **adhesive; impregnation, introfaction.**
wetware In the computer industry, a person's brain.
wet winding See **filament winding, wet-winding.**
wheatstone bridge See **electrical wheatstone bridge.**
wheelabrating See **deflashing, wheelabrating.**
whisker See **reinforcement, whisker.**
whisker, metallic A fiber composed of a single crystal of metal. See **fiber, metallic; reinforcement, whisker.**
white-box A phrase used to describe a device whose method of working is ill-defined or not understood. See **coefficient of scatter; test, white-box and black-box.**
whitener See **calcium carbide; calcium carbonate; optical brightener agent; stress whitening.**
white-ware See **alumina white-ware.**
wholesaler One who buys in large quantities and sells in smaller quantities to a retailer who sells to the consumer. With plastic materials, the quantities bought by the wholesaler may vary from a fraction of a car load to many car loads. See **business; sales.**
wicking Passage of a liquid or air in a filled plastic, particularly reinforced plastics. With RPs, penetration is longitudinally along or between fibers that have been encased in plastic during fabrication. This action could be damaging to the performance of the product.
Wiegand pendulum See **test, Wiegand pendulum heat.**
Wilhelm, Gottfried See **calculus.**
wine taste test See **test, organoleptic.**
winder See **extruder take-off winder.**
window See **plastic, light switchable; processing window; safety glass.**
wipe-in See **decorating, fill-and-wipe.**
wire and cable From the beginning of the electrical industry, plastics have been used for their insulation, semiconductivity, and jacketing capabilities. Various plastics are used to meet performance requirements that are electrical, mechanical, chemical, thermal, and environmental. Extensive amounts of polyethylene plastics are used that

include low- to high-density compounded grades, cross-linked grades, and dry swellable grades that prevent water penetration. See **extruder wire and cable.**

wire coating See **coating; extruder coating and lamination.**

wire draw-down ratio and draw-ratio balance See **draw-down ratio; extruder wire and cable die draw-down ratio.**

wire frame modeling See **computer modeling.**

wire train See **extruder wire and cable train.**

wire-wrapping diameter A measure of wire ductility. It is the minimum diameter to which wire can be wound without causing failure.

witness, expert See **legal matter: expert witness.**

Witt theory See **dyeing, Witt theory of.**

wood Industrial lumber products represent about 23wt% or 45vol% of all industrial raw materials consumed worldwide (about the same volume as building and construction—concrete, bricks, sand, etc). Wood is a cellular form of cellulose; cellulose is the most abundant of all naturally occurring organic compounds. A number of wood's components combine into complex molecules and fibers. Because of its fibrous structure, wood's properties are directional. They have a high strength-to-weight, good insulation, and cushioning properties. Wood is hygroscopic, absorbing water and moisture in its cell walls, where it induces volume changes. It makes up at least one-third of all vegetable matter worldwide. The United States has more trees now than it did in 1776. See **building and construction; cellulose, alpha; injection molding, nonplastic; plastic and lumber; plastic consumption; plastic growth: urea plastic.**

wood and plastic See **plastic lumber; wood, compreg; wood compressed.**

wood, balsa Balsa is the lightest and softest wood used commercially. It is one-fourth the weight of cork. About 90wt% of all balsa is used as a sandwich core material. The major market for balsa is the marine industry. See **sandwich core material.**

wood classification Woods are classified into softwoods and hardwoods. Softwoods are trees that generally have needlelike or scalelike leaves. The term does not refer to the actual hardness of the wood. The hardwoods include trees whose wood may be hard or soft.

wood composition board A product that is usually made by reducing wood to small particles and reforming it into a rigid board. Bonding is by adhesion developed from the natural adhesive action of the wood substance or through the addition of various binders, such as starch to plastics (phenolic, etc.). See **adhesive, plywood; binder.**

wood, compreg A contraction of *compressed plastic impregnated wood* that usually refers to wood assembly veneer layers and other wood-plastic impregnated combinations. See **impregnation; wood-plastic impregnated.**

wood compressed Wood that has been subjected to high compression pressure to increase its density with or without plastics. It is usually supplied in the form of a laminate in which plastics have been incorporated by drying the wood and using a vacuum. Also called *densified wood* or *laminated wood*. See **laminate wood; wood, ply-.**

wood cord A unit volume of cut wood stacked in a pile that measures 4 × 4 × 8 ft (1 × 1 × 2 m) containing a volume of 128 ft^3 (3.6 m^3).

wood flour Finely divided dry wood that is used as a filler principally in thermoset plastics (phenolics and ureas). Particle size is such that they usually pass through a 40 mesh screen. Various types of wood can be used. See **flour; screen.**

wood graining A group of processes (extrusion, coating, laminating, injection molding, etc.) that are used to impart a woodlike appearance to such products as sheet- or molded-shaped products. See **mold cavity, etched; photoetching tool.**

wood, hard- The wood from trees with leaves, not needles. The wood of hardwoods may be hard or soft. This classification is usually given to trees such as oak, birch, and maple. See **wood, soft-.**

wood impregnation See **wood, compreg.**

wood, laminated A high-pressure bonded wood product that is composed of layers of wood with plastic, such as phenolic, as the laminating agent. See **wood compressed; wood, ply-.**

wood, modified A wood whose properties have been improved by plastics, chemicals, thermal treatments, or compression treatments.

wood, petrified A wood whose original chemical components have been replaced by silica. The change occurs in such a way that the original forms and structure of the wood are preserved. The Petrified Forest in Arizona is known for its petrified wood.

wood-plastic composite process The processes that are used to produce wood-plastic products include extrusion, injection molding, compression molding, and vacuum-bag molding. See **plastic and lumber.**

wood-plastic impregnated (WPI) Plastic-loaded wood (impregnated) results in significantly increased performance for the wood, such as higher mechanical properties, better hardness, longer life, and better rot resistance. Originally (1909), most of the plastics used were phenolics. By the 1950s, acrylic and vinyls were used. Vinyl polymerization was an improvement over phenolic condensation polymerization, which left by-products, such as water, that had to be removed. A vacuum is used to evacuate the air from dry wood. The wood is put into a bath of plastic solution. The soaking period, like the evacuation period, depends on the type and structure of the wood. Curing of plastics is usually by a radiation rather than regular polymerization reactions. Also called *compreg*. See **impregnation; plastic and lumber; polymerization.**

wood-plastic profile Extruded wood-plastic composite profiles can contain at least 70wt% wood and produce a woodlike appearance. These products compete in different markets, particularly the building and construction market and waterfront locations, like boating docks.

wood pressure process The treatment of timber to prevent decay by forcing a preservative, such as creosote, zinc chlorides, or zinc formate, into the cells of wood. See **zinc formate.**

wood pulp A form of cellulose that is obtained from wood or vegetable matter by prolonged cooking with chemicals. It is used in the manufacture of paper and as a source of cellulose. See **cellulose acetate plastic process; molding, pulp; paper; viscous process.**

wood pulping The disintegration of wood (chemically) into its fibrous components. The separation of wood chips occurs by chemical treatment to dissolve the lignin that bonds the fibers together.

wood pulp, paper Processed cellulose fibers that are made into paper. See **fabric, nonwoven mechanical; paper.**

wood, soft- A tree that in most cases has needlelike or scalelike leaves. This term has no reference to the actual hardness of the wood. For example, most softwoods, such as pines, are actually harder in texture than hardwoods. See **wood, hard-.**

wood specific gravity (s.g.) Most commercial wood in the United States is 0.35 to 0.65 s.g. Most woods are below 1, with certain species, such as the black ironwood in Florida or the axemaster in Belize, at 1.42 (89 lb/ft^3). The s.g. of commercial grades of balsa wood is 0.11 to 0.16 (6 to 10 lb/ft^3).

wood substitute Recycled plastics are used to replace wood in different applications, such as water floating platforms, park benches, dividing fences or walls, outdoor furniture, and patios. See **Corian; plastic and lumber; recycled plastic.**

wood veneer A thin sheet of wood, generally within the thickness range of 0.01 to 0.25 in. (0.3 to 6.3 mm), that is used in laminations. See **adhesive, edge joining; veneer.**

woof See **yarn fill.**

working life See **pot life; shelf life.**

work center One or more machines or workstations of similar capabilities grouped together for control purposes.

woven fabric See **fabric, woven.**

world trade The following list provides total population in millions for various countries: Argentina 33, Australia 18, Austria 8, Bangladesh 117, Belgium 10, Brazil 158, Burma 38, Cambodia 10, Canada 27, Chile 14, China 1,170, Colombia 34, Cuba 11, Czech Republic 10, Denmark 5, Ecuador 11, Egypt 56, Ethiopia 51, European Community 350, Finland 5, France 57, Georgia 6, Germany 80, Greece 10, Haiti 6, Hungary 10, India 886, Indonesia 195, Iran 61, Iraq 18, Ireland 4, Israel 5, Italy 58, Japan 125, Korea-North 22, Korea-South 44, Malaysia 18, Mexico 92, Netherlands 15, New Zealand 3, Nigeria 89, Norway 4, Pakistan 121, Peru 23, Philippines 67, Poland 38, Portugal 10, Romania 23, Russian Federation 150, Saudi Arabia 17, Singapore 3, South Africa 42, Spain 39, Sudan 28, Sweden 9, Switzerland 7, Syria 13, Taiwan 21, Thailand 58, Tunisia 8, Turkey 60, Ukraine 52, United Kingdom 58, United States 260, Venezuela 21, Vietnam 69, and Yugoslavia 10. See **gross domestic product; legal matter: tariff; market.**

World Wide Web (www) A network of computer electronic sites that are linked to form a global electronic network for transmitting information in text, graphs, audio, video formats, and so on. See **website.**

wrinkle A crease. For example, wrinkles can occur when the surface of a coating dries before the inner layer dries, allowing the inner layer to shrink while it is drying. Surface drying can be retarded by the addition of solvents with a high boiling point. With reinforced plastics, an imperfection on the surface can have an appearance of a wave molded into one or more plies of fabric or other reinforcing material.

writing, technical See **technical writing.**

wysiwyg An acronym for "what you see is what you get."

X

xanthate A salt of the series of xanthic acids that is used as an accelerator in certain plastics. See **viscose process.**
x-axis The horizontal axis in the plane of a material used as 0° reference. The y-axis is in the plane of the material perpendicular to the x-axis, and the z-axis is the reference axis that is normal to the x-y plane. The term *plane* or *direction* is also used in place of *axis*. See **directional property, abscissas; directional property, ordinate; y-axis.**
Xenoy GE's trade name for its family of thermoplastic polyester plastic blends.
xerographic material See **printing, xerography.**
x-radiation See **radiation, diffraction.**
x-ray An electromagnetic wave of short wavelength 0.01 to 50 Angstrom units, which is produced when streams of electrons impinge on matter. See **lead.**
x-ray analysis See **test, nondestructive radiography.**
x-ray diffraction The technique of using the diffraction of x-rays to study the structure of plastics to determine their crystalline structure and to measure their particle size. See **light scattering.**
x-ray film See **digital imaging.**
x-ray fluorescence See **processing via fluorescence spectroscopy; spectrometer, x-ray fluorescence.**
x-ray ionization method A method of x-ray diffraction in which the intensity of the diffracted beam is measured by means of an ionization chamber. See **ionization.**
x-ray microscopy A technique of examining x-rays by means of a microscope. In a variation called *point, projection,* an enlarged image is obtained from x-rays emitted from a pinhole point source. It is useful for studying the structure of plastics such as reinforced plastics, foams, and fibers. See **molecular-arrangement structure.**
x-ray radiograph An x-ray film, plate, or paper that is placed at the image plane and is used for recording an x-ray image of the object being examined. See **digital imaging.**
x-ray scanning carbon-fiber reinforced plastic See **test, nondestructive carbon-fiber reinforced-plastic x-ray scanning.**
x-ray scattering, long period A morphological parameter that is obtained from small-angle x-ray scattering. It is usually equated to the sum of the lamellar thickness and the amorphous thickness. See **amorphous plastic scatter.**
x-ray sensor See **sensor, nuclear.**
x-ray sorter See **bottle sorter, optical.**
x-ray spectrography See **spectrograph, x-ray.**
x-ray spectroscopy An instrument for producing the x-ray spectrum of a material and measuring the wavelengths of its various components by observing their diffraction by crystals of known lattice spacing. This method identifies crystalline compounds by the characteristic x-ray spectrum that is produced when a sample is irradiated with a beam of sufficiently short-wavelength x-radiation. Diffraction techniques produce a fingerprint of the atomic and molecular structure of a compound and are used for identification. Fluorescence techniques are used for quantitative elemental analysis. Also called *roentgen spectrometry* or *x-ray spectrometry*. See **chemistry, analytical; differential scanning calorimetry; molecular-arrangement structure.**
XTC plastic See **reinforced plastic, XTC.**
XT plastic See **plastic, XT.**
Xydar Amoco Performance Products Inc.'s tradename for its family of liquid-crystal polymers.
xylene A colorless aromatic hydrocarbon liquid. It is used as a solvent, in the manufacture of polyester plastics, and as a chemical intermediate.
xylenol plastic A phenolic-type plastic that is produced by condensing xylenol (a coal tar derivative) with aldehyde.
xylylene plastic In a coating process, a plastic that is capable of producing extremely thin (microns) pinhole-free coatings of outstanding conformity and thickness uniformity by the chemistry of the xylylene monomer. A substrate is exposed to a controlled atmosphere of pure gaseous monomer p-xylylene (XP). The process is a vapor deposition polymerization (VDP). The monomer itself is thermally stable but kinetically unstable. Although it is stable as a gas at low pressure, on condensation it spontaneously polymerizes to produce the coating of a high-molecular-weight linear poly(p-xylylene) (PPX). Also called *polyxylylene* or *PX*. See **chemical vapor deposition.**
xylyl mercaptan An efficient peptizing agent for natural rubber. It is also used as a bleaching agent in the preparation of pale crepe rubber.
x-y recorder An instrument that is designed to plot graphs in a Cartesian-coordinated system. A Cartesian-coordinated system is a two-dimensional system having an abscissa (x-axis) and an ordinate (y-axis). The recorder plots the relation between these two variables, which can be stress and strain. See **directional property, abscissa; directional property, ordinate; stress-strain curve.**
x-y-z axes See **x-axis.**
x-y-z blow molding See **blow molding, extruder, three-dimensional.**

Y

yard A unit of measure that in the United States equals 0.9144018 m and in the United Kingdom equals 0.914399 m.

yardage The number of yards of yarn, roving, or strand per pound of glass fibers; the reciprocal of weight per yard; the length of a product on a reel.

yarn A generic term for an assemblage of twisted fibers or strands, either natural or manufactured, that form continuous yarn (thread) suitable for use in weaving or otherwise interweaving into textile materials. It is used in plastic-coated materials, in reinforced plastics, and as a filler with plastics. See **fiber.**

yarn breaking length A measure of the breaking strength of reinforcing yarn. The length of a yarn specimen's weight is equal to the breaking load.

yarn, carded A yarn that is made from fibers that have been carded but not combed in the manufacturing process. Most spun yarns are of this type. See **fiber carding.**

yarn, combed A yarn that is made from fibers that have been carded and combed in the manufacturing process. Combed yarns are generally cleaner, smoother, and more lustrous than carded yarn.

yarn, combination A ply of yarn that is twisted from single yarns of different fibers, such as glass and rayon fibers.

yarn, commingled A hybrid yarn that is made with two types of materials that are intermingled in a single yarn. For example, thermoplastic filaments may be commingled with carbon fibers. See **hybrid; recycling commingled plastic.**

yarn construction number A system that shows yarn construction—namely, the cut of the single yarn, the number of plies, and whether reinforcements are present. Yarns up to nine-cut, inclusive, have three-digit construction numbers with the first digit indicating the cut, the second the number of plies, and the third the number of reinforcements. Thus, a No. 1420 yarn has 14-cut, two-ply, and no reinforcement. See **fiber count.**

yarn, continuous filament A yarn that is formed by twisting two or more continuous filaments into a single, continuous strand.

yarn count The relationship between yarn weight and length. The basic unit is 10. See **fabric count; fiber denier; tex.**

yarn denier specification See **fiber denier.**

yarn designation The number of original singles (strands) that are twisted and the number of these units that are plied to form a yarn or cord. The first letter indicates glass composition, the second letter represents whether it is continuous or staple fiber, and the third letter indicates the diameter range of the individual fiber. For example, CD identifies type E glass with continuous fiber (C) of 0.00023 in average fiber diameter (D). See **fiberglass type.**

yarn density, linear Mass per unit length of yarn expressed as g/cm or its equivalent.

yarn distortion In woven fabrics, a condition in which the symmetrical surface appearance of a fabric is altered by the shifting or sliding of warp or filling yarns.

yarn end A group of filaments before they are twisted. After the filaments are twisted, they become a yarn. There are warp yarn thread, thread, fiber, and roving.

yarn fill The transverse threads or fibers in a woven fabric; those fibers running perpendicular to the warp. Also called *weft* or *woof.* See **weft; yarn warp.**

yarn, final twist The number of turns per unit length in a single yarn component of a plied yarn or the plied yarn component of a cabled yarn as the component lies in the more complex structure. Also called *"as-is" twist.*

yarn grex A universal yarn numbering system in which the yarn number is equal numerically to the weight in g/10,000 m.

yarn, knot tenacity The tenacity or knot strength in grams per denier (g/den) of a yarn where an overhand knot is put into the filament or yarn being pulled to show sensitivity to compressive or shearing forces.

yarn, multifilament A multitude of fine continuous filaments, often of 5 to 100 individual filaments, usually with some twist in the yarn to facilitate handling. Their sizes are described in denier and range from 5 to 100 deniers. The larger deniers, even in the thousands, are usually obtained by plying smaller yarns together.

yarn nib A small thickened location in a yarn or fabric.

yarn number See **yarn count.**

yarn package A length or parallel lengths of yarn in a form suitable for handling, storage, or shipping.

yarn, plied The number of single yarns that are twisted together to form a plied yarn. One of the layers makes up a stack or laminate. Normally the yarns are twisted together. Those collected without twist are also used in reinforced plastic lay-ups. See **reinforced plastic.**

yarn, spliced The joining of two ends of glass-fiber yarn or strand, usually by means of an air-drying adhesive.

yarn strand count The number of strands in a plied yarn or roving.

yarn stress, critical longitudinal The longitudinal stress necessary to cause internal slippage and separation of a spun yarn. It is the stress necessary to overcome the interfiber friction that develops as a result of twist.

yarn tenacity In yarn manufacture and textile engineering, the strength of a yarn or a filament for its given size. Numerically it is the grams (of breaking force) per denier unit of yarn or filament size (gpd). The yarn is usually pulled at the rate of 5 in./m (12 cm/m). Tenacity equals breaking strength (g) divided by denier. Also called *breaking strength*. See **fiber denier.**

yarn, turn per inch (TPI) A measure of the amount of twist produced on a yarn, tow, or roving during its processing cycle. It represents the lead rate of a hoop layer at a specified bandwidth. See **yarn twist, direction of.**

yarn twist, balanced An arrangement of twists in a combination of two or more strands that do not kink or twist when the yarn produced is held in the form of an open loop. For example, single-S twist fiber plied with a Z fiber results in "balancing" the fibers. The amount of twist with plying provides many combinations that are useful in various applications. Filament yarns can exist in an almost twistless form, but this is not the case for staple fiber yarns. See **cordage; dope; kink; twist, direction of yarn.**

yarn twist, direction of In yarn or other textile strand, the spiral turns about its axes per unit length. Twist may be expressed as turns per inch. The letters S and Z indicate the direction of twist, which refers to whether the twist direction conforms to the middle-section slope of the particular letter. See **twist, direction of yarn.**

yarn twist, hawser The construction of cabled yarn, cord, or rope in which the single and first ply twists are in the same direction and the second ply is in the opposite direction.

yarn warp **1.** The yarn running lengthwise in a woven fabric. **2.** A group of yarns in long lengths and approximately parallel, put on beams or warp reels for further textile processing including weaving, knitting, dyeing, etc. See **yarn fill.**

yarn weight See **fiber denier.**

y-axis A line perpendicular to two opposite parallel faces. See **x-axis.**

yellowing Developing a yellow color in near-white or near-transparent plastics (coatings, film, etc.). It is the result of degradation on exposure to light, heat aging, or weathering. Usually it is measured in terms of a yellowness index. See **pigment, fluorescent; yellowness index.**

yellowness An attribute by which an object color is judged to depart from colorless or white toward yellow. Negative values denote blueness.

yellowness index A number that is computed by a given procedure from colorimetric or spectrophotometric data and that indicates the degree of departure of an object color from colorless or from a preferred white toward yellow. See **colorimeter.**

yellow oxide An inorganic pigment that is based on iron oxide.

yield The ratio of actual yield to theoretical yield multiplied by 100.

yield, plastic Nonelastic deformation. See **deformation.**

yield point In engineering terms for tensile, compression, or shear test specimens, the first stress in a material, less than maximum attainable stress, at which the strain increases at a higher rate than the stress. It is at the point where permanent deformation of a stressed specimen starts to take place. Only materials that exhibit yielding have a yield point. For materials that do not exhibit a yield point, yield strength serves the same purpose as the yield point. See **elastic-plastic transition.**

yield point elongation In materials that exhibit a yield point, the difference between the elongation at the completion and the elongation at the start of discontinuous yielding.

yield strength The stress at the yield point where a material exhibits a specified limiting deviation from the proportionality of stress to strain. The lowest stress at which a material undergoes plastic deformation. Below this stress, the material is elastic; above, the material is viscous. It is often defined as the stress needed to produce a specific amount of plastic deformation, such as 0.2% change in length.

yield strength, offset The stress at which the strain exceeds by a specific amount (the offset) which is an extension of the initial, approximately linear, proportional portion of the stress-strain curve. It is expressed in force per unit area.

yield, theoretical The amount of product that is predicted to be present after all the limiting reagent has been utilized. See **compounding.**

yield value The stress, either normal or shear, at which a marked increase in deformation occurs without an increase in stress (load).

Y-joint See **filament-winding knuckle area.**

Young's modulus See **modulus of elasticity.**

Z

zanja An irrigating canal.
zapping See **film, electrostatic charge.**
z-average, molecular weight See **molecular mass; molecular-weight determination.**
z-axis The reference axis perpendicular to x and y axes. See **x-axis; y-axis.**
Z-blade mixer See **mixer, sigma-blade.**
Z calender A four-bowl calender in which rolls 1 and 2 are situated in a horizontal plane. Roll 3 is below roll 2, 1 and 4 are therefore offset. Also called *Z-cylinder.* See **calender.**
Z direction See **stress, plane.**
zein plastic A naturally occurring, high-molecular-weight copolymer of amino acids that are linked to peptide bonds, derived from corn. It is a member of the protein family of plastics with the main member being casein plastic. It has been used for fibers, films, and coating but is now rarely used.
zeolite A naturally occurring hydrated silicate of calcium and aluminum. This name is also given to synthetic substances with a similar crystalline structure. Both natural and artificial types are used extensively for cracking catalysts, detergent builders, water softening, and molecular sieves. See **catalyst, zeolite.**
Zepel DuPont's trade name for its family of fluorocarbon textile finishes that are used as a durable oil and water repellent.
Zerion Dow Chemical's trade name for its family of methyl methacrylate-styrene copolymer.
zero absolute temperature See **temperature, absolute zero.**
zero air-void curve See **air-void curve, zero.**
zero balance High performance for materials and fabricating processes that avoids excessive losses that were not originally included in the design. When something is gained, something usually is lost; the goal is not to let that loss influence product performance.
zero bleed **1.** A fabrication procedure that does not allow loss of plastic during solidification or cure. **2.** Prepreg or other reinforced plastic made with the amount of plastic matrix desired in the final part, such that no plastic is lost or has to be removed during processing. See **laminate; reinforced plastic.**
zero crossing See **mean crossing.**
zero defect The ultimate performance for any supplier in terms of meeting design performance requirements at the lowest cost. Unfortunately, quality-control procedures are usually taken only after production and are based on the acceptance of a certain level of failure. Effective quality standards must be applied early in the process and be fully supported by management. See **failure, fault-tree analysis of; FALLO approach; feature defect, zero; mean and standard deviation; quality control defined; statistical assessment; tubing, microbore; World of Plastics Reviews: Thinking Like a Manager and Managing for the Long Run.**
zerogel See **gel, zero-.**
zero power resistance The resistance of a thermister or resistance temperature detector element with no power being dissipated. See **temperature sensor.**
zero time The time when the given loading or constant conditions are initially obtained in creep and stress relaxation tests, respectively. See **creep; relaxation; stress.**
Zetafin Dow Chemical's trade name for its family of ethylene vinyl acetate plastics.
Ziegler-Natta catalyst See **catalyst, Ziegler-Natta.**
Ziegler process A process for the low-pressure linear polymerization of ethylene and stereospecific polymerization of polypropylene. The product is a high-density plastic or elastomer. It is named for Karl Ziegler, the German scientist who was corecipient (with Giullo Natta, Italy) of the Noble Prize in 1963. See **catalyst; polymerization; polymerization history.**
Zimmermann reaction See **chemical reaction, Zimmermann.**
zinc (Zn) An inexpensive metal whose alloys are stronger, tougher, and more ductile than aluminum (Al). In addition to its metal- and die-casting alloy forms, Zn is also used to extend the life of other materials, such as steel (by hot dipping or electrogalvanizing), plastic and rubber (as an aging inhibitor), and wood (in paint coatings). It is a strong alternative to Al in die or mold castings since they can last five to 10 times longer. Dimensional tolerances can often be tight enough to reduce or eliminate the need for machining that Al requires. See **injection molding, nonplastic; tolerance.**
zinc acetate A white, monoclinic, pearly luster, crystalline-plate structure that has a faint acetone odor. It is soluble in water and alcohol. It is used as a cross-linking agent for plastics. See **cross-linking.**
zinc alloy See **die-casting alloy; mold material.**
zinc borate Any white, amorphous powder of various compositions that contains various amounts of zinc oxide and boric acid. They are used as fire retardants in PVC, PVDC, polyesters, and polyolefins, usually in combination with antimony oxide.
zinc carbonate ($ZnCO_3$) A white, crystalline powder. It is soluble in acids, alkalies, and ammonium salt solutions and insoluble in water. It is used as a fireproofing filler.
zinc coating See **recycling steel with vinyl scrap.**

zinc diethyl dithiocarbamate An ultra accelerator that is too scorchy for use as a sole accelerator in dry rubber compounding but is used in latex work.
zinc formate Toxic, white crystals that are soluble in water and insoluble in alcohol. It is used as a catalyst, weatherproofing agent, and wood preservative. See **wood pressure process.**
zinc gray Zinc dust used as a pigment.
zinc hydroxide ($Zn(OH)_2$) A colorless, water soluble crystal that decomposes at 125°C (257°F). It is used as a chemical intermediate and in rubber compounding.
zinc isopropyl xanthate An ultra accelerator of vulcanization at temperatures as low as 38°C (100°F). In mixtures with dithiocarbamate accelerators, it is used for room-temperature vulcanization. See **adhesive, room-temperature cure.**
zinc molding See **injection molding, nonplastic.**
zinc nitrate Colorless lumps of crystals, that are soluble in water and alcohol. It is used as a latex coagulant, reagent, and acidic catalyst. See **catalyst; latex.**
zincograph See **printing, photoengraving.**
zinc oxide (ZnO) An infusible amorphous light white powder that is obtained by heating zinc carbonate. It is an activator in rubber compounds containing organic accelerators. In polychloroprene, it is considered to be the accelerator rather than the activator. Its use as a filler and white pigment in plastics is rather obsolete. It has a high ultraviolet light absorbing power of all commercially available pigments.
zinc stearate A white powder that is used as a lubricant and dusting agent.
zinc sulfide (ZnS) A naturally occurring white amorphous precipitate that is used in a compound to exhibit phosphorescence. See **phosphorescence.**
zink mark A shallow depression in the surface that is visible because of a sharply defined rim or a roughened surface somewhat similar to a sink mark. See **sink mark.**
zipper In 1851 Elias Howe, Jr. patented a device composed of a series of clasps and ribs that would join two pieces of material. Even though the concept had merit, he abandoned it to concentrate on the sewing machine. Howe's invention remained forgotten until the turn of the twentieth century, when it evolved into what is known now as the zipper. It was first used to close money belts and tobacco pouches and was not widely accepted by the apparel industry until the 1940s. Various materials are used, including brass, aluminum, and plastics (especially polyesters and acetals). See **grass, synthetic; injection molding; Velcro strip.**
zipper plastic bag See **extruder-blown film-bag manufacturing; thermoforming, form, fill, and seal.**
zirconium (Zr) A material of construction that is used in many chemical environments because of its excellent corrosion resistance. It is one of a few metals that can be used in chemical processes requiring alternate contact with strong acids and alkalies. Zr and its alloys are resistant to HCl at all concentrations and at temperatures above the boiling point. See **acid; chemical reaction; hydrochloric acid.**
zirconium hydride (ZrH_2) A flammable, gray-black powder that is used as a reducing agent.
zirconium oxide A white amorphous powder that is used as a pigment when good electrical properties are required.
Z-N and metallocene catalyst comparison See **catalyst, metallocene, Z-N, comparison.**
Z-N catalyst See **catalyst, Ziegler-Natta.**
zone A location in a plasticating screw. See **screw feed zone; screw metering; screw transition zone.**
zone axis A group of crystal planes that are all parallel to one line is called the *zone axis.*
zorro Tropical American timber trees (Astronium graveolens) with the color of mahogany.
Z-twist See **twist, direction of yarn.**
zymoplastic A substance that is not an enzyme but is believed to participate in the formation of enzymes. See **catalyst, enzyme; decomposition; degradation.**
zymurgy The branch of applied chemistry that has to do with fermentation processes. See **decomposition; waste.**

Appendix A

LIST OF ABBREVIATIONS

The following extensive guide to abbreviations used in the plastics industry worldwide includes some of those used throughout this book. Some terms have more than one abbreviation or share the same abbreviation.

A	acetaldehyde
A	acetone, acrylate, acrylonitrile, alkyd, amide, etc.
A	ampere
A	angstrom
A	area
AA	acetic aldehyde
AA	acrylamide
AA	Aluminum Association
AA	atomic absorption
AAAS	American Association of the Advancement of Science
AAc	acrylic acid
AAC	amyl acetate
AAE	American Association of Engineers
AAES	American Association of Engineering Societies
AAEZ	American Association of Enterprise Zones
AAGR	average annual growth rate
AAm	acrylamide
AAMI	Association for the Advancement of Medical Instrumentation
AAMA	American Architectural Manufacturing Association
AAR	Association of American Railroads
AAS	acrylate-styrene-acrylonitrile
AAS	Association of the Advancement of Science
AAS	atomic absorption spectroscopy
AATC	American Association of Textile Chemists
AB	antiblock
ABA	acrylonitrile-butadiene-acrylate
ABA	American Bar Association
abbr.	abbreviation
ABC	activity-based costing
ABC	atomic, biological, chemical
ABEA	azobisformamide
ABL	Allegheny Ballistic Laboratory
ABR	acrylate-butadiene rubber
ABC	activity based costing
—	acetal (see POM)
abs.	absolute
ABS	absorbance
ABS	acrylonitrile-butadiene-styrene
AC	acetal (polymer)
AC	advanced composite
AC	alternating current
AC	cellulose acetate
ACC	Automotive Composites Consortium
ACCS	advanced composite construction system
ACF	activated carbon fiber
ACG	Advanced Composites Group
ACGIH	American Conference of Government Industrial Hygienists
ACI	American Concrete Institute
ACM	acrylate rubber
ACM	acrylic acid ester rubber
ACM	advanced cure monitor
ACM	American Chemical Manufacturers
Acn	acetone
ACMS	Advanced Centre for Material Science (India)
ACN	acrylonitrile
ACPES	acrylonitrile-chlorinated polyethylene-styrene
ACR	acrylated chlorinated rubber
ACR	acrylic fiber
ACS	acrylonitrile-chlorinated polyethylene-styrene
ACS	American Ceramic Society
ACS	American College of Surgeons
ACS	Australian Custom Service
ACT	amplitude correlation time
ACTC	Advanced Composite Technology Consortium
A/D	analog-to-digital (conversion) (also called ADC)
AD	apparent density
AD	average deviation
ADA	adipic acid
ADA	Americans with Disabilities Act
ADC	allyl diglycol carbonate (also see CR-39)
ADC	ammonium dichromate
ADC	analog-to-digital conversion (also called A/D)
ADCB	asymmetric double cantilever beam
adh.	adhesive
ADS	additive delivery system
ADS	air dried sheet
AE	acoustic emission
AE	auxiliary equipment
AEB	average extent of burning
AEC	acrylonitrile-ethylene-styrene
AECO	epichlorohydrin rubber

AED	atomic emission detector
AEF	advanced engineering fiber
AES	acrylonitrile-ethylene-propylene-styrene
AF	U.S. Air Force
AF	asbestos fiber
AFB	phthalic anhydride
AEPDM	acrylonitrile/ethylene-propylene-diene/styrene
AES	acrylonitrile-ethylene-styrene
AFBM	Anti-Friction Manufacturers' Association
AFCMA	Aluminum Foil Container Manufacturers' Association
AFI	aluminum fiber
AFK	asbestos fiber reinforced plastic
AFMA	American Furniture Manufacturers' Association
AFML	Air Force Material Laboratory
AFNOR	Association Francais de Normalization
AFPA	American Forest and Paper Association
AFPR	Association of Foam Packaging Recyclers
AFRP	aramid fiber reinforced plastic
Ag	silver
AGA	American Gas Association
AGE	aging resistance
AGE	allyl glycidyl ether
AHMA	American Hotel and Motel Association
AHT	aluminum hydroxide trihydrate
AI	artificial intelligence
AIA	Aerospace Industries Association
AIA	allylamine
AIAA	American Institute of Aeronautics and Astronauts
AIC	Automation Industry Council
AIChE	American Institute of Chemical Engineers
AIDS	acquired immune deficiency syndrome
AIMBE	American Institute for Medical Biological Engineering
AIMCAL	Association of Industrial Metallizers, Coaters, and Laminators
AIMMPE	American Institute of Mining, Metallurgical, and Petroleum
AIP	American Institute of Polymers
AISE	Association of Iron and Steel Engineers
AISI	American Iron and Steel Institute
AJT	air-jet texturing (yarn)
AK	acrylate rubber
Al	aliphatic
Al	aluminum
alc	alcohol
Al_2O_3	aluminum trioxide (alumina)
ALU	arithmetic-logic unit
AMA	Adhesives Manufactures' Association
AMA	American Medical Association
AMAB	acrylonitrile-methyl acrylate-acrylonitrile-butadiene (rubber)
AMBA	American Mold Builders Association
AMC	alkyd molding compound
AMD	acrylamide
AMMA	acrylonitrile-methyl-methacrylate
AMP	automated molding plant
AMPP	acrylic modified polypropylene
AMS	aerospace material specification
AMS	alpha methyl styrene
amu	atomic mass unit
AN	acrylonitrile
ANFI	Association of Nonwoven Fibers Industry
ANI	aniline
ANM	acrylate rubber
ANRA	African Natural Rubber Association
AN/S	acrylonitrile-styrene copolymer
ANSI	American National Standards Institute
ANTEC	Annual Technical Conference (SPE)
AO	antimony oxide
AO	antioxidant
AOCS	American Oil Chemists' Society
AOZ	antiozonant
APA	American Plywood Association
APA	amorphous polyamide
APC	air pollution control
APC	American Plastics Council
APD	ablative photodecomposition
APEC	Asian Pacific Economic Committee
APET	amorphous polyethylene terephthalate
APF	Association of Plastics Fabricators
APG	automatic pressure gelation process
API	addition reaction polyimide
API	American Paper Institute
API	American Petroleum Institute
APME	Association of Plastics Manufacturers in Europe
APO	aluminophosphate
APP	atactic polypropylene
APPR	Association of Postconsumer Plastics Recyclers
approx.	approximate
APRA	Australian Plastics Research Association
APT	automatically programmed tool
APU	auxiliary power unit
APY	annual percentage yield
AQ	aqueous
AQL	acceptable quality level
Ar	argon
Ar	aromatic
AR	acceptable risk
AR	alkaline resistant
AR	aramid fiber
AR	aromatic
AR	aspect ratio
ARC	abrasion-resistant coating

ARL	Army Research Laboratory
ARM	Association of Rotational Molders
ARMI	Association of Rubber Manufacturers of India
ARP	advanced reinforced plastics
ARP	aromatic polyester
ARPA	Advanced Research Projects Agency
As	arsenic
AS	asbestos
ASA	acrylic-styrene-acrylonitrile
ASA	American Standard Association
ASA	American Statistical Association
ASAP	as soon as possible
ASBE	American Society of Body Engineers
ASC	Adhesives and Sealants Council
ASC	American standard code
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Interchange
ASD	adjustable speed drive
ASEP	American Society of Electroplated Plastics
ASL	antislip
ASM	American Society for Metals
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASQC	American Society for Quality Control
AS/RS	automated storage and retrieval system
Assn	Association
Assoc.	Association
AST	antistatic
ASTM	American Society for Testing Materials
ASW	antisubmarine warfare
ASWAN	Association of Southwest Asian Nations
ATA	Air Transport Association
ATB	average time of burning
ATC	assembly test chip
ATE	alumina trihydrate
ATH	aluminum trihydrate
atm.	atmosphere or atmospheric pressure
ATMI	American Textile Manufacturers' Institute
at. no.	atomic number (colloquialism); official is Z
ATO	antimony trioxide
ATP	advanced technology program
ATPE	atomic amine terminated polyether
ATV	all-terrain vehicle
at. wt.	atomic weight
Au	gold
av.	average
avdp	avoirdupois
AW	atomic weight
AWJ	abrasive-water (cutting) jet
AWS	American Welding Society
AWWA	American Water Works Association
AZ	azodicarbonamide
AZI	American Zinc Institute

b	width of section
B	benzyl, butadiene, butyl, butyrate, etc.
B	boron
Ba	barium
BA	bachelor of arts
BA	blowing agent
BA	butyl acrylate
BAc	butyl acetate
BAR	barrier
BaS	barium sulfate
BASA	British Adhesives and Sealants Association
BASIC	beginners all-purpose symbolic instruction code
BATF	U.S. Bureau of Alcohol, Tobacco, and Firearms
bbl	barrel
BBP	benzyl butyl phthalate
BC	biocomputing
BCB	biocompatible
BCB	bisbenzocyclobutene
BCS	binary coded decimal
BCl_3	boron trichloride
BCO	block copolymer
BD	bidirectional
BD	Brownian dynamics
bd. ft.	board foot
BDP	biodegradable (aliphatic) polyester
Be	beryllium
BE	binding energy
BeCu	beryllium copper
BEO	butadiene epoxide
BER	bit error rate
BES	benzoic acid
BF	boron fiber
BFRL	Building and Fire Research Laboratory (NIST)
BHHS	British Health and Human Resources
Bhn	Brinell hardness number
Bi	bismuth
BI	biological indicator
BIB	bag-in-box
BIE	boundary integral equation
BIF	benchmark interface format
BING	Federation of European Rigid Polyurethane Foam Association
BIOS	basic input/output system
Bis-A	bisphenol-A
bit	binary digit
BLK	black
BM	back molding

BM	bag molding
BM	bending moment
BM	blow molding
BMC	bulk-molding compound
BMI	bismaleimide
BMW	broad molecular weight
BMWD	broad molecular-weight distribution
Bn	billion
Bnz	benzene
BO	biaxially oriented
BOA	benzyl octyl adipate
BOA	broad ocean area
BOM	bill of material
BOPP	biaxially oriented polypropylene
bp	boiling point
BP	British Petroleum
BP	polybutadiene rubber
BPA	bisophenol-A
bpd	barrels per day
BPET	branched polyethylene terephthalate
BPF	British Plastics Federation
bpi	bits per inch
BPI	Banbury processability index
BPO	benzyl peroxide
BPTA	British Polymer Training Association
BQ	becquerel
BR	blow ratio (also see BUR)
Br	bromine
BR	bronze
BR	burst strength
BR	butadiene rubber
BRBA	Buy Recycled Business Alliance
BS	bachelor of science
BS	barium stearate
BS	British Standard
BS	butadiene styrene rubber
BSC	bottle stress crack
BSI	British Standard Institute
BSR	bearing stress ratio
BTA	methylmethacrylate-butadiene-styrene terpolymer
BTC	Bottling Technology Council
BTK	benzyldithiocarbamate
BTT	breakthrough time
Btu	British thermal unit
BTV	Brookfield thermoset viscosity
BTX	benzene-toluene-xylene
Bu	informal abbreviation for butyl
BuAer	Bureau of Aeronautics
BuMed	Bureau of medicine
BUN	blood urea nitrogen
Buna	polybutadiene
BUR	blowup ratio (see also BR)
Butyl	butyl rubber
BVM	bulk viscosity modifier
BW	bandwidth
BX	Bureau of Export Administration
BzMA	benzyl methacrylate
BzO	benzoyl peroxide
c	centi (10^{-2})
C	carbonate, cellulose, chloride, etc.
C	calorie (also cal)
C	carbon
C	casting
C	cellophane
C	Celsius
C	Centigrade (preference Celsius)
C	channel black
C	compliance
C	composite
C	coulomb
C	stiffness constant
Ca	calcium
ca.	circa (or approximate)
CA	carbonization agent
CA	cellulose acetate (CAc)
CA	compressed air
CAA	Clean Air Act
CAB	cellulose acetate butyrate
$CaCO_3$	calcium carbonate (lime)
CAc	cellulose acetate
CAD	charged area development
CAD	compact audio disc
CAD	computer-aided design
CAD	computer-aided disc
CADA	computer-aided data acquisition
CADD	computer-aided design and drafting
CAE	computer-aided engineering
cal	calorie (see also C)
CAF	calcium fluoride
CAFE	corporate average fuel economy
CAFG	conductive anodic filament growth
CALED	calculated
CAM	composition and makeup
CAM	*Compressed Air* magazine
CAM	computer-aided manufacturing
CAM	computer-assisted makeup
CAMG	computer-aided molecular graphics
CAMP	Clean Air Management Partnership
CAMPUS	computer-aided material preselection by uniform standards
CAN	cellulose acetate nitrate
CAO	computer-aided optimization
CAP	cellulose acetate propionate
CAP	computer-aided planning
CAP	controlled-atmosphere packaging
CAPE	computer-assisted polymer engineering
CAPP	chlorinated atactic polypropylene
CAPP	computer-aided process planning
CAR	carbon fiber
CARE	Cooperative for American Relief Everywhere

CAS Chemical Abstracts Service
CAT computer-aided technology
CAT computer-aided testing
CAT computer-aided tomography
cb columbium
CB carbon black
CB collapsible bottle
CBA chemical blowing agent
CBA cost-benefit analysis
CBAO chain-breaking antioxidant
CBOT Chicago Board of Trade
CBR butadiene rubber
CBT computer-based training
CC centrifugal casting
CC cone calorimeter
CCA cellular cellulose acetate
CCO copper chrome arsenate
CCC Chlorine Chemistry Council
CCC computer command center
CCD chemical composition distribution
CCD charge couple device
CCE coefficient of crystalline expansion
CCL commodity control list
CCM compression composite molding
CCM computer cost modeling
CCPIA China Plastics Processing Industry Association
CCR chemically coupled reinforcement
CCT cone calorimeter test
CCV Composite Concept Vehicle
cd candela
Cd cadmium
CD compact disk (disc)
CD composition distribution
CD continuous vulcanization
CDA cellulose diacetate
CDB conjugated diene butyl
CDER Center for Drug Evaluation and Research (FDA)
CDMA Chemical Development and Marketing Association
CD-ROM compact disc read-only memory
CE cellulosic plastic
CE chemical engineer
CE compensation effect (aging)
CE cost effective
CEFIC European Industry Council (French acronym)
CEG carboxy end group
CEL cellulose
CEN European Committee for Standardization
CEO chief executive officer
CEPP Chemical Emergency Preparedness Program
CEQA California Environmental Quality Act
CERCLA Comprehensive Environmental Response Compensation and Liability Act (or Superfund)
CET controlled-emission technology
CF carbon fiber
CF cresol formaldehyde
CFA chemical foaming agent
CFC chlorofluorocarbon
CFCC continuous fiber ceramic composite
CFE chlorotrifluoroethylene
cfm cubic foot per minute
CFP collated fibrillated polypropylene
CFR Code of Federal Regulations
CFR cresol-formaldehyde plastic
CFRM continuous filament roving and mat
CFRP carbon fiber reinforced plastics
CFRTP continuous fiber reinforced thermoplastics
CFT critical flocculation temperature
CFT cup foam test
cg center of gravity
CG chopped glass
CG computer graphics
CGATS Committee for Graphic Arts Technologies Standards
CGCT constrained geometry catalyst technology
CGMP current good manufacturing practice
CGNP current gross national product
CGPM Conference General des Poids et Measures (French General Conference on Weights and Measures)
CGTT critical gel transition temperature
CHDM cyclohexanedimethanol
CHR chemical resistance
Ci curie
CI chemical indicator
CI chemical ionization
CI clearness index
CI Composite Institute (SPI)
CIA computer-image analysis
CID coating in depth
CIE Commission Internationale de l'Eclairage (French International Commission on Illumination)
CIIM computer-integrated injection molding
CIIT Chemical Institute
CIL Canada Industries Ltd.
CIM computer-integrated machine
CIM computer-integrated manufacturing
CIM confusion in manufacture
CIP cleaning-in-place
CIP computer-integrated production
CIP craze initiation pressure
CIV composite intensive vehicle
Cl chlorine
CIQ computer-integrated quality

CIR	cumarone indene resin
CIS	Commonwealth of Independent States (formerly USSR)
Cl	chlorine
CL	clay
CL	computerized library
CLA	cross-linking agent
CLD	compression load deflection
Cl-HC	chlorinated hydrocarbon
CLF	cutter location file
CLPT	classical laminate plate theory
CLTE	coefficient of linear thermal expansion
cm	centimeter
CM	Cincinnati Milacron
CM	compression molding
CMA	Chemical Manufacturers' Association
CMAT	color matching aptitude test
CMC	carboxymethyl cellulose
CMC	ceramic matrix composite
CMC	continuous-molding compound
CMM	composite metal matrix
CMM	coordinate measuring machine
CMP	code of management practices
CN	cellulose nitrate (celluloid)
CNAMM	Coalition of North American Machinery Manufacturers
CNC	computer numerical control
CNG	compressed natural gas
CNG	continuous glass
CNS	copper nonstaining (vulcanization)
c/o	care of
Co	cobalt
Co.	company
CO	carbon monoxide
CO	cotton
CO_2	carbon dioxide
COD	cash on delivery
coef.	coefficient
COF	coefficient of friction
COFO	coforming (Dow Chemical)
CONEG	Coalition of Northeast Governors
COP	copolyester
COPA	copolyamide
Co-Pak	corona packaging (National Can's process)
COPE	copolyester
COPE	Council on Packaging in the Environment (previously COPPE)
Corp.	Corporation
COS	coefficient of optical stress
COTSE	corotating twin-screw extruder
cP	centipoise
CP	Canadian Plastics
CP	cellulose propionate
CP	ceramic powder
CP	chemically pure
CP	chlorinated polyethylene
CP	coefficient of permeability
CP	cross-polarization
CPC	cavity pressure control
CPC	continuous process control
CPC	critical point control
cpd	compound
CPE	chlorinated polyethylene
CPE	copolyester elastomer
CPEC	Centrally Planned Economy Countries
CPET	chlorinated polyethylene terephthalate
CPET	crystalline polyethylene terephthalate
CPI	Canadian Plastics Institute
CPI	condensation reaction polyimide
CPI	consumer price index
cpm	cycles per minute
CPM	cold pressure molding
CPP	cast polypropylene
CPRR	Center for Plastics Recycling Research (Rutgers University)
cps	characters per second
cps	cycles per second
CPSA	Consumer Product Safety Act
CPSC	Consumer Product Safety Commission
CPSF	counter pressure structural foam
CPTC	Canadian Plastic Training Centre
CPU	central processing unit
CPVC	chlorinated polyvinyl chloride
CPW	chlorinated paraffin wax
Cr	chromium
CR	catalyst residue
CR	chemical recycling
CR	chemical resistance
CR	chloroprene rubber
CR	compression ratio
CR	controlled release
CR	controlled rheology
CR	cross-reference
CR-39	diethylene glycol bis-allyl carbonate (see also ADC and PADC)
CR	polychloroprene rubber (neoprene)
CRA	controlled release additive
CrC	chromium carbide
CRC	crystallization rate coefficient
CRE	constant rate of extension
CRI	Carpet and Rug Institute
CRI	Container Recycling Institute
CRI	cure-rate index
CRL	constant rate of load
CRM	certified reference material
CrN	chromium nitride
CRP	carbon reinforced plastics
CRP	creep resistance
CRS	cold rolled steel
CRS	Committee on Resin Statistics (SPI)
CRS	creep-rate spectroscopy

CRT	cathode ray tube
CRT	constant rate of transverse
CRTSE	counterrotating nonintermeshing twin-screw
CS	casein
C/S	cycles per second
CSA	Canadian Standards Association
CSD	carbonated soft drink
CSF	casein formaldehyde
CSI	silicone rubber
CSM	chopped strand mat
CSM	continuous strand mat
CSPE	chlorosulfonated polyethylene
CST	classical shell theory
CRT	critical surface temperature
CSW	consumer solid waste
CSWS	Council of Solid Waste Solutions (SPI)
CT	chain transfer
CT	computerized tomography
CT	continuous thread
CT	triacetate
CTA	cellulose triacetate
CTA	chain transfer agent
CTD	cumulative trauma disorder
CTE	coefficient of thermal expansion (use CLTE)
CTFA	Cosmetic, Toiletries, and Fragrance Association
CTFE	chlorotrifluorethylene
CTL	close tolerance
cu	cubic
Cu	copper
Cu	curie
CU	computer unit
CU	control unit
cu. in.	cubic inch
cu. m.	cubic meter
CV	cardiovascular
CV	coefficient of variation
CV	computer vision
CV	constant viscosity
CV	continuous vulcanization
CV	regenerated cellulose
CV	viscose
CVC	chemical vapor curing
CVD	chemical vapor deposition
CVI	chemical vapor infiltration
CVR	computerized virtual reality
CW	coarse wood
CWA	Clean Water Act
CZ	carbazole

d	denier (preferred DEN)
d	density
3D	three dimension
3DP	three-dimensional printing
D	decyl
D	derivative
D	diameter
D	dimensional (like 2D, 3D, etc.)
DA	diffuse attenuation
D/A	digital-to-analog (conversion)
DABCO	diazobicyclooctane
DAC	diacetate, diacetate
DAC	diallyl chlorendate
DACC	data acquisition and command center
DAF	diallyl fumarate
DAF	direct-access file
DAIP	diallyl isophthalate
DAM	days after manufacture
DAM	diallyl maleate
DAM	diallyl metaphthalate
DAMS	dental amalgam mercury syndrome
DAOP	diallyl orthophthalate
DAP	diallyl phthalate
DAT	data acquisition terminal
DAT	digital audio tape
dB	decibel
DBE	dibasic ester
DBM	dibutyl maleate
DBM	dip blow molding
DBMS	database management system
DBP	dibutyl phthalate
DBS	dibutyl sebacate
DBS	direct broadcasting satellite
DBTT	ductile-to-brittle transition temperature
DC	design control
DC	direct current
DC	Dow Chemical
DC	Dow Corning
DCIM	direct compounding injection molding
DCP	dicapryl phthalate
DCPD	dicyclopentadiene
DCDT	direct current displacement transducer
DD	dipolar decoupling
D&D	dos and don'ts
DDA	didecyl adipate
DDC	dynamic differential calorimeter
DDP	didecyl phthalate
DDR	disc ring reactor
DDR	draw down ratio
DE	diatomaceous earth
DEA	dielectric analysis
DEA	differential enthalpic analysis
DEC	decompose
DEHP	di (2-ethexy) phthlate
DEN	denier (or D)
Den/Fil	denier per filament
DEP	diethyl phthalate
DETDA	diethyltoluenediamine
DF	dissipation factor
DFA	design for assembly

DFCA	design for competitive advantage
DFD	design for disassembly
DFM	design for manufacturability
DFMA	design for manufacturability/assembly
DFQ	design for quality
DFR	design-for-recycling
DGA	differential gravimetric analysis
DGT	dynamic gel temperature
DH	degree of hydrolysis
DHP	diheptyl phthalate
diam	diameter
DIDP	di-iso-decyl phthalate
DHP	diheptyl phthalate
DIBP	diisobutyl phthalate
DIDA	diisodecyl adipate
DIF	diffusion coefficient
DIM	design integrated manufacturing
DIN	Deutsches Institut fur Normung (German Standard)
DIOA	diisooctyladipate
DIOP	diisooctyl phthalate
DIS	dispersibility
DIS	draft international standard (ISO)
distn.	distillation
DIV	division
DLG	design law group
DMA	direct money access
DMA	dry as molded
DMA	dynamic mechanical analysis
DMC	dimethyl carbonate
DMC	dough molding compound
DMC	dynamic matrix control
DMC-12	DeLorean motor car (plastic body)
DMDI	diphenylmethane diisocyanate
DMP	dimethyl phthalate
DMR	device master record
DMS	dynamic mechanical spectroscopy
DMT	dimethyl ester of terephthalic acid
DMTA	dynamic mechanical thermal analysis
DMW	demineralized water
DMW	drain, waste, and vent
DN	*Design News*
DN	Deutscher Normenausschus
DNA	deoxyribonucleic acid
DNA	dinonyl adipate
DNC	direct numerical control
DNP	dionyl phthalate
DOA	dioctyl adipate
DOC	U.S. Department of Commerce
DOC	dissolved organic compound
DOD	degree of disorder
DOD	U.S. Department of Defense
DODP	dioctyl decyl phthalate
DOE	U.S. Department of Energy
DOE	design of experiment
DOP	dioctyl phthalate
DOS	U.S. Department of State
DOS	dioctyl sebacate
DOS	disc operating system
DOT	U.S. Department of Transportation
DOT	dual-ovenable tray
DOTP	dioctyl terephthalate
Dow	Dow Chemical
DOX	design of experiments methodology
DOZ	dioctyl azelate
DP	degree of polymerization
DP	average degree of polymerization
DP	dew point
DPA	diphenolic acid
DPC	Degradable Plastics Council
DPC	degree of packing cutoff
DPCF	diphenyl cresyl phosphate
DPF	density performance factor
DPM	discrete polymer modifier
DPOF	diphenyl 2-ethylhexyl phosphate
DPSC	data processing service center
DPSU	diphenylsulfone
DR	degree of reaction
DR	drag reduction
DR	draw ratio
DRAM	dynamic random access memory
DRAW	direct read-after write
DRB	draw ratio balance
DRC	design rules checking
d-RDF	density-refused-derived fuel
DRI	Dow rheology index
DS	degree of saturation
DS	degree of substitution
DR	draw ratio
DRE	Draw resonance eliminator
DRR	disc ring reactor
DRS	dielectric relaxation spectroscopy
DS	dimensional stability
DS	degree of substitution
DS	dust suppressed
DSC	differential scanning calorimeter
DSD	Duales System Deutschland (German Recycling System)
DSI	die slide injection
DSM	demand-side management
DSMO	dimethyl sulfoxide
DSPC	direct shell production casting
DSQ	German Society for Quality
DSR	dynamic stress rheometer
DSS	digital satellite system
DSSP	deep submergence system program
DST	direct screw transfer
DSV	dilute solution viscometer
DTA	differential thermal analysis
DTGA	differential thermogravimetric analysis
DTH	direct to home
DTM	desk top manufacture
DTMA	dynamic thermomechanical analysis
DTP	desk top publishing

DTS	decision technology system
DTUL	deflection temperature under load
DV	design verification
DV	devolatilization
DV	direct vulcanization
DVD	digital-versatile-disc
DVEA	dynamic vulcanizate elastomer alloy
DVNR	dynamically vulcanized natural rubber
DVR	dimensional velocity research
DVR	design value resource
DVR	Druckverfomungsrest (compression set/German)
DVR	dynamic velocity ratio
DWP	design with plastics
DWV	drain-waste-vent (piping)
dyn	dyne
E	elongation
E	ethanol
E	expoxidized, ester, ethyl, ethylene, etc.
E	modulus of elasticity or Young's modulus
E	ethylene (monomer)
E_C	modulus, creep (apparent)
E_R	modulus, relaxation
E_S	modulus, secant
EA	elastomeric alloy
EA	energy absorber
EA	epoxy acrylate
EA	ethyl acrylate
EAA	ethylene acrylic acid
EAc	ethyl acetate
EAC	environmentally assisted cracking
EAD	extrusion area diagram
EAM	electronic accounting machine
EAN	European article number
EAR	ethylene acrylic rubber
EB	electron beam
EB	elongation at break
EB	ethyl benzene
EBA	ethylene butyl acrylate
EBM	extrusion blow molding
EBR	edge-bead reduction
EC	electrochemical
EC	ethyl cellulose
EC	European Community
ECB	electrochemical battery
ECH	epichlorohydrin
ECL	electrochemical luminescence
ECM	electronic countermeasure
ECN	electrochemical noise
ECN	engineering change notice
ECO	epichlorhydrin rubber
ECP	electrical conducting polymer
ECP	electrochemical polymerization
ECPE	extended chain polyethylene
ECTFE	ethylene-chlorotrifluoroethylene
ECVM	European Council of Vinyl Manufacturers
ED	electron diffraction
EDA	ethylene diamine
EDB	electronic database
EDC	ethylene dichloride
EDC	Eurocomp design code
EDD	engineering design database
EDF	Environmental Defense Fund
EDG	electronic dot generation
EDI	electronic data interchange
EDI	electronic data interface
EDM	electric discharge machining
EDM	engineering data management
EDM	engineering development model
EDP	electron diffraction pattern
EDP	electronic data processing
E-Draw	erasable direct read after write (information disc)
EDR	external draw ratio
EDR	extrusion draw ratio
E/E	electrical/electronics
EEA	ethylene-ethyl acrylate
EEC	European Economic Community
EEO	equal employment opportunity
EET	electronic excitation transfer
EET	electronic excitation transport
EFU	entropy of fusion
e.g.	for example
EG	ethylene glycol
E-glass	glass fiber
EGM	external gas molding
EHS	environmental, health, and safety
EI	electron impact
EI	emotional intelligence
EI	modulus (times) moment of inertia (or stiffness)
EIA	Electronic Industries Association
FIFO	first-in/first-out
EIP	electronic image processing
EL	elastomer
FLC	fuzzy logic control
ELL	electroluminescent lamp
ELO	epoxidized linseed oil
ELS	elastic light scattering
EMA	ethylene-methyl acrylate
EMAA	Envelope Manufacturers' Association
EMAA	ethylene methyl acrylate acid
EMAC	ethylene-methyl acrylate copolymer
Email	electronic mail
EMB	electromechanical battery
EMC	electromagnetic compatibility
EMC	electromagnetic compliance
EMC	epoxy molding compound
emf	electromagnetic frequency
EMF	electromotive force
EMI	electromagnetic interference

EMP	electromagnetic pulse
EMPP	elastomer modified polypropylene
EMR	electromagnetic radiation
EMR	external mold release
EMS	electromagnetic shielding
EMS	environmental management system
EMT	elastomer modified thermoplastic
EMU	electromagnetic unit
EMU	European Monetary Union
EnBA	ethylene normal butyl acrylate
EnC	encapsulation
EO	electro-optic
EO	ethylene oxide (also EtO)
EOQ	economic order quantity
EOR	enhanced oil recovery
EP	epoxy, epoxide, or ethylene-propylene
E/P	ethylene/propylene
EPA	enthalpimetric analysis
EPA	U.S. Environmental Protection Agency
EPC	ethylene-plasma coated
EPC	ethylene propylene rubber
EPD	electrical power disturbance
EPD	ethylene-propylene diene
EPDM	ethylene-propylene diene monomer
EPF	expandable plastic foam
EPIC	Environmental and Plastic Institute of Canada
EPM	ethylene-propylene rubber
EPP	expandable polypropylene
EPR	ethylene-propylene rubber
EPRI	Electric Power Research Institute
EPS	expandable polystyrene
EPT	ethylene-propylene diene terpolymer
ER	epoxy resin
ERM	elastic recovery molding
ERRA	European Recovery and Recycling Association
ES	electrical schematic
ES	emission spectroscopy
ES	engineering specification
ES	extrudate swell
ESA	electrostatic assist
ESC	environmental stress cracking
ESCA	electron spectroscopy for chemical analysis
ESCR	environmental stress cracking resistance
ESD	electronic system development
ESD	electrostatic discharge
ESD	electrostatic dissipation or discharge
ESE	electron spin echo
ESI	electron spectroscopic imaging
ESI	ethylene-styrene interpolymer
ESM	electron scanning microscopy
ESO	epoxidized soya bean oil
ESMS	electrospray mass spectrometry
ESR	electron spin resonance
est.	estimate
EST	electric surface treatment
ESU	electrostatic unit
Et	ethyl group
ET	ethylene toluene
ET	extruder's technician
et al.	and others
etc.	and so forth
ETE	engineering thermoplastic elastomer
ETER	perfluoroethylene propylene terpolymer
ETFE	ethylene terafluoroethylene
ETI	ethylene terminated imidothioether
EtO	ethylene oxide
ETP	engineering thermoplastic
EU	entropy unit
EU	European Union
EUPC	European Association of Plastics Converters
EUPE	European Union of Packaging and Environment
Euro	European currency (started 1 January 1999 and completed 31 December 2001)
EUROMAP	European Committee of Machine Manufacturers for the Rubber and Plastics Industries (Zurich, Switzerland)
eV	electron volt
EV	electric vehicle
EV	exclude volume
EVA	ethylene-vinyl acetate
E/VAC	ethylene/vinyl acetate copolymer
EVAL	ethylene-vinyl alcohol copolymer (or EVOH)
EVD	extrusion volume diagram
EVE	ethylene vinyl ether
EVOH	ethylene-vinyl alcohol copolymer (or EVAL)
EW	equivalent weight
EWC	equilibrium water content
EWF	essential work of fracture
Ex	extrusion
ExCM	extrusion continuous molding
ExM	extrusion molding
EXTR	extruder or extruding
F	coefficient of friction
F	Fahrenheit
F	Faraday
F	fluoride, formaldehyde, phosphate, etc.
F	force
F_2	fluorine
FA	fatty acid
FA	fumaric acid
FAA	U.S. Federal Aviation Administration
FAAS	flame atomic absorption spectrometer
fab	fabric
FAB	fast atom bombardment

FALLO Follow ALL Opportunities
FAMC flexible automated manufacturing concept
FAN flow analysis network
FAO U.N. Food and Agricultural Organization
FAP fastener accreditation progress
FAP food additive petition
FAST fabric assurance by simple testing
FB fishbone
FBA Flexible Packaging Association
FBR fluid bed reactor
FBVF fiber (glass) backed vacuum thermoforming
FC flow casting
FC fluorocarbon
FCBA fluorochlorobromacetaldehyde
FCC U.S. Federal Communications Commission
FCC first critical concentration
FCP fatigue crack propagation
FDA flocculating and dewatering apparatus
FDA Food and Drug Administration
FDEMS frequency-dependent electromagnetic sensor
Fe iron
FE finite element
FEA U.S. Federal Energy Agency
FEA finite element analysis
FEM finite element modeling
FEM flexural elastic modulus
FeO ferrous oxide (iron oxide)
FEP fluoronated ethylene propylene
FF furan-formaldehyde
FFF field-flow fractionation
FFM friction force microscopy
FFR finite fiber reinforcement
FFRP flax fiber reinforced plastics
FFS form-fill-seal
FFTA Foundation of Flexographic Technical Association
FG food grade
FHA U.S. Federal Highway Administration
FHSA Federal Hazardous Substances Act
FHWA U.S. Federal Highway Administration
FI factor of ignorance
FIB flow induced birefringence
FIF foam-in-fabric
FI-FO first-in, first-out
File 13 waste, paperwork, etc. to throw away/destroy
FIM film insert molding
FIM finite element method
FIM full indicator movement
FIR full indicator reading
Fl flax
FLC fuzzy logic control
FLK flock
FM ferromagnetic
FM foamable
FM formal
FMC flexible manufacturing cell
FMCT fusible metal core technology
FMEA failure mode and effect analysis
FML flexible manufacturing line
FML flexible membrane liner
FMR Factory Mutual Research
FMS flexible manufacturing system
FMT flow molding technique
FMV fair market value
FMW formulated molecular weight
FOB free on board
FOI freedom of information
FP fluoroplastic
FP freeze point
FPA Flexible Packaging Association
FPI Foodservice and Packaging Institute
FPL Forrest Products Laboratory
fpm feet per minute
FPO flexible polyolefin
FPVC flexible polyvinyl chloride
FQC free to qualified customer
FR fiber reinforcement
FR flame retardant
FR flow rate
FRCA Fire Retardant Chemicals Association
FRP fiber reinforced plastic
FRTM flexible resin transfer molding
FRTP fiber-reinforced thermoplastic
FRTS fiber-reinforced thermoset
FS factor of safety
FS flexible strength
FS fluorosilicone
FSI flame spread index
FSTS Fire, Smoke, and Toxicity Standard
FT Fisher-Trosch
FTA fault tree analysis
FTC U.S. Federal Trade Commission
FTIR Fourier transform infrared
FU follow up
FUN furan
FV free volume
FW filament winding
FWA fluorescent whitening agent
FY fiscal year
FYI for your information

g gram
G gauss
G gelatin
G geosynthetic
G giga (10^6)
G gravity

G	shear modulus (modulus of rigidity)
G	torsional modulus
Ga	gallium
GA	genetic algorithm
GAIN	gas-assisted injection
GAIM	gas-assisted injection molding
gal	gallon
GAO	U.S. General Accounting Office
GAP	glycidyl acrylate polymer
gas	gasoline
GATT	General Agreement on Tariffs and Trade
GB	gigabyte (billion bytes)
GB	glass bead
GC	gas chromatography
GC	glass coupled
GCD	U.S. government contracts directory
GCP	gas counterpressure
g/Den	gram per denier
GDP	gross domestic product (see also GNP)
GD&T	geometric dimensioning and tolerancing
Ge	germanium
GE	General Electric
GEX	generalized exponential sum
GF	glass fiber
GFA	glass flake
GFM	generalized fracture mechanics
GFRP	glass fiber-reinforced plastic
gf/Tex	gram-force per Tex
GHK	Gewerkschaft Holzund Kunststoff (wood and plastic processors, Germany)
GHP	guarded hot plate
GID	gas internal pressure
GIGO	garbage in, garbage out
GIM	gas injection molding
GINA	graphical integrated numerical analysis
GIPT	granular injected paint technology
GIT	gas injection technology
GLAT	government lot acceptance testing
Gly	glycol
GM	General Motors
GM	glass mat
GMA	glycidyl methacrylate
GMA	Grocery Manufacturers of America
GMAW	gas metal arc welding
GMC	granular molding compound
GMI	geometric modeling system
g-Mol	gram-molecule
GMP	good manufacturing practice
GMTP	glass mat reinforced thermoplastic
GNP	gross national product (GDP replaced GNP in the United States 1993)
gov't	government
GP	general purpose
GP	gutta percha
GPa	giga Pascal
GPC	gel permeation chromatography
GPC	graphics performance characterization
gpd	grams per denier
GPD	gas phase deposition
GPEEK	glass-reinforced polyetheretherketone
GPI	Glass Packaging Institute
GPIA	general purpose instrumentation bus
gpm	gallons per minute
GPMS	general purpose metering screw
GPPS	general purpose polystyrene
GPS	general purpose screw
gr	grain
GR	glass reinforced
GR-1	butyl rubber (former U.S. acronym)
GRAS	generally recognized as safe
GRG	general rubber goods
GRN	granular
GR-N	nitrile rubber
GRP	glass fiber-reinforced plastic
GRP	graphite powder
GRS	styrene-butadiene rubber (former U.S. acronym)
GS	glass sphere
GS	green seal
GSA	U.S. General Service Administration
GSC	gas solid chromatography
GSE	gas structural element
GT	glass tape
GTM	gas transfer mold
GTP	group transfer polymerization
GTR	gas transmission rate
Gy	gray
GY	graft yield
h	hour
H	Henry
H	heptyl
H	hydrogenation
H	hysteresis
H_2	hydrogen
HA	hindered amine
HA	human hair
HAF	high abrasion furnace (black)
HALS	hindered amine light stabilizer
HAO	higher alpha olefin
HAR	high aspect ratio
HAS	hindered amine stabilizer
HAZ	heat-affected zone
HB	hole burning
HB	Brinell hardness number
HBT	horizontal burn test
HC	hydrocarbon
HCC	high color channel (black)
HCCN	honeycomb core crush number
HCF	high coefficient of friction

HCFC	hydrochlorofluorocarbon
HCl	hydrogen chloride
HCPP	high crystalline polypropylene
HCR	heat-cured rubber
HCV	heat-curable vulcanizate
HDB	hydrostatic design basis
HDBK	handbook
HDC	hydrodynamic chromatography
HDG	highly dispersed graphite
HDI	hexamethyl diisocyanate
HDP	hispanic employment program
HDPE	high-density polyethylene (also PE-HD)
HDT	heat deflection temperature
HDT	heat distortion temperature
HDTUL	heat deflection temperature under load
HDTV	high definition television
He	helium
HEA	hydroxyethyl acrylate
HEC	hydroxyethyl cellulose
HEIB	high-energy ion-beam irradiation
Hep	heptane
Hex	hexane
HEXA	hexamethylenetetramine
HF	heat flow
HF	high frequency
HF	hydrogen fluoride
HFC	high-frequency current
HFC	hydrogen fluorocarbon
HFE	hydrofluoroether
HFGD	high-frequency glow discharge
HFM	heat flow meter
HFP	hexafluoro propylene
Hg	mercury
HH	hydrazine hydrate
HHV	high calorific value
HI	high impact
HIC	household and industrial chemicals
HID	high-intensity diffusion
HIM	high-intensity mixing
HIMA	Health Industry Manufacturers' Association
HIP	hot isostatic press
HIP	hot isotactic pressing
HIPP	hemi-isotactic polypropylene
HIPS	high-impact polystyrene
HK	hardness, Knoop
HM	high modulus
HMA	hot-melt adhesive
HMB	hexamethylbenzene
HMC	high-strength molding compound
HMDI	diisocyanate dicyclohexylmethane
HMF	heavy-metal free
HMR	Hazardous Materials Regulation
HMRM	hot-melt road marking
HMS	high-melt strength
HMW	high molecular weight
HMW-HDPE	high-molecular-weight high-density polyethylene
HMWPE	high-molecular-weight polyethylene
HMWR	high-molecular-weight rubber
H-NBR	hydrogenated nitrile rubber
HNP	high-nitrile plastic
HNR	high-nitrile resin
H_2O	water
H-P	Hagen-Poiseuille
HP	high performance
HP	high pressure
hp	horsepower
HP	hot plate
HPF	high-pressure forming
HPLC	high-performance liquid chromatography
HPLC	high-pressure liquid chromatography
HPM	hot-pressure molding
HPO	hydrogen peroxide
hr	hour
HR	heat resistance
HR	high resilience
HRc	hardness Rockwell cone
HRC	high-resolution chromatography
HRIM	horizontal reaction-injection molding
HRIT	high-rate impact test
HRR	heat-release rate
HS	heat stabilized
HS	high-percent solids
HSc	hardness scleroscope number
HSE	heat sealable
H_2SO_4	hydrogen sulfate (sulfuric acid)
HSR	high shear rate
HT	high temperature
HTBA	high-temperature blowing agent
HTE	hydroxyl terminated polyether
HTF	heat-transfer fluid
HTP	high-temperature polymerization
HTS	high-temperature superconductor
HTV	high-temperature vulcanization
HUD	U.S. Housing and Urban Development
HV	hardness, Vickers number
HV	high viscosity
HVAC	heating, ventilation, and air conditioning
HVEM	high-voltage electron microscopy
HVI	high-volume instrumentation
HVOF	high-velocity oxy-fuel
Hx	hexyl
HY	hybrid
HYP	hydroxyproline
Hz	goat hair
Hz	Hertz (cycles)
I	initiator
I	integral
I	iodine

I	moment of inertia
I_{abs}	intensity of absorbed light
IAI	impact-after-impact
IAPD	International Association of Plastics Distributors
IB	isobutylene
IBACOS	integrated building and construction solutions
IBC	internal bubble cooling
IBC	iodine binding capacity
IBI	isoprene-butadiene-isoprene copolymer
IBM	injection blow molding
IC	integrated circuit
ICBM	intercontinental ballistic missile
ICC	U.S. Interstate Commerce Commission
ICI	Imperial Chemical Industries
ICM	injection-compression molding
ICM	intermolecular cross-linked macromolecule
ICMA	International Card Manufacturers' Association
ICP	inherently conducting polymer
ICP	intrinsically conductive plastic
ICP	intrinsically connecting plastic
ICR	internal cooling system
ICST	Imperial College of Science and Technology
ICT	intramolecular charge transfer
ID	industrial design
ID	internal diameter
IDB	internal double bond
IDE	investigation device exemption
IDF	insulation displacement function
IDM	intelligent decision module
IDP	inherently dissipative polymer
IDPA	isophorone diamine
IDSA	Industrial Designers Society of America
IDT	initial decomposition temperature
IDT	ink-diffusion technology
IDT	intelligent-data terminal
IDT	interdigital transducer
i.e.	that is
IEC	inelastic energy curve
IEC	International Electrochemical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEN	interpenetrating elastomer network
IEP	isoelectric point
IF	integer-fold
IFR	intumescent flame retardant
IGA	isothermal gravimetric analysis
IGC	inverse gas chromatography
IGM	internal gas molding
IGP	internal gas pressure
IH	inhibitor
IH	in-house
IHBM	in-house blow molding
IHPN	interpenetrating homopolymer network
IIE	International Institute of Entomology
III	International Isocyanates Institute
IIR	butyl rubber (isobutylene-isoprene rubber)
ILD	indentation load deflection
ILS	interlaminar shear
IM	impact modifier
IM	infusion molding
IM	injection molding
IM	intermediate modulus
IM	polyisobutylene rubber
IMC	in-mold coating
IMC	internal model control
IMC	intramolecular cyclization
IMD	Injection Molding Division (of SPE)
IMD	in-mold decorating
IMI	Industrial Materials Institute of NRC
IML	in-mold labeling
IMM	injection-molding machine
IMR	internal mold release
IMT	ion microtomography
IMW	intermediate molecular weight
in.	inch
In	indium
IN	inorganic
Inc.	Incorporated
INB	inline bidding
INS	inelastic neutron scattering
insol	insoluble
I_o	intensity of incident light
I/O	input/output
IO	ionomer
IOI	I owe industry
IOP	Institute of Physics (UK)
IOT	initial oxidation temperature
IOU	I owe you
IPA	isophthalic acid
IPC	interfacial polycondensation
IPDF	isophoron diisocyanate
IPE	intelligent processing equipment
IPI	isoprene diisocyanate
IPM	intelligent processing of materials
IPN	interpenetrating polymer network
ipr	inches per rack
IPS	impact-resistant polystyrene
ips	inch per second
IPT	injected paint technology or in-mold painting technology
IPTS	international practical temperature scale
IQI	image quality indicator
Ir	iridium
IR	infrared
IR	isoprene rubber (synthetic)

IRAS	infrared reflection-absorption spectroscopy
IRC	International Rubber Conference
IRDG	instability-related delamination growth
IRE	internal reflection element
IRIA	Indian Rubber Industries Association
IRIS	integrated real-time inspection system
IRM	interference reflection microscopy
IRPI	infrared polymerization index
IRS	Institute for Standard Research
IRS	internal reflection spectroscopy
IRS	Internal Revenue Service
IRT	insect resistant treated
IS	injection stamping
IS	insoluble sulphur
ISBM	injection stretch blow molding
ISC	intersystem crossing
ISD	in-mold surface decoration
ISF	in-mold surfacing film
ISF	International Science Foundation
ISIF	interfacial stress intensity factor
ISM	injection-spin welding
ISO	International Standardization Organization or International Organization for Standardization
ISO	reactive isocyanate
ISP	isopropyl alcohol
ISS	interfacial shear strength
ISS	ion spectroscopy scattering
IST	irreversible stochistic transition
ISTS	impulsive stimulated thermal scattering
ISV	internal state variable
IT	information technology
IT	innovative technology
ITC	isothiocyanate
ITE	information technology equipment
ITGA	isothermogravimetric analysis
ITO	indium-tin oxide
ITP	interpenetrating thickening process
ITS	interfacial testing system
ITT	impact transition temperature
IU	international unit
IUPAC	International Union of Pure and Applied Chemistry
IV	inherent viscosity
IV	intravenous
IV	intrinsic viscosity
IVD	in vitro diagnostic
IVE	isobutyl vinyl ether
J	joule
J_p	polar moment of inertia
JEOL	Japan Electron Optics Laboratory
JIS	Japanese Industrial Standard
JIT	just-in-time
JIT	just-in-tolerance
JM	jet molding
JND	just noticeable difference
JRP	jute reinforced plastic
JS	jet spinning
JSPS	Japan Society for Promotion of Science
JSR	Japanese SBR
JSW	Japan Steel Works
Ju	jute
JUSE	Japanese Union of Science and Engineering
JWTE	Japan Weathering Test Center
K	bulk modulus of elasticity
K	carbazole
K	coefficient of thermal conductivity
K	Kelvin
K	potassium
K	temperature conductivity factor
K	Kunststoffe (German for plastic)
KAB	keep America beautiful
KB	kilobyte (1,000 bytes)
kB	knowledge-based
KBE	knowledge-based engineering
KBS	knowledge-based system
kc	kilocycle
kcal	kilogram calorie
KE	kinetic energy
Ker	kerosene
Ket	ketone
kg	kilogram
KGM	kinetic gelation model
KI	potassium iodide
KIE	kinetic isotope effect
KISS	keep it short and simple
KISS	keep it simple and safe
KISS	keep it simple, stupid
KK	thousand
Km	kilometer
KM	Kubelka-Munk theory
KMC	kneader molded compound
km/h	kilometer per hour
KO	knockout
KOH	potassium hydroxide
kPa	kilopascal
Kr	krypton
KrF	krypton fluoride
KRF	Korea (South) Research Foundation
ksi	thousand pounds per square inch (psi × 10^3)
kV	kilovolt
KWIC	keyword-in-context
KWOC	keyword-out-of-context
Kz	cashmere wool
l	length
L	litre (U.S. liter)
LAB	laboratory

LAN	local area network
LANL	Los Alamos National Laboratory
LAOS	low-amplitude oscillatory shear
LAPP	labeled atactic polypropylene
LAS	linear alkylate sulfonate
LASE	load at specified elongation
LASER	light amplification by stimulated emission of radiation
LAT	lubrication approximation theory
lb	pound
lbf	pound-force
LBR	low birefringence
LBR	solution butadiene rubber
LC	liquid chromatography
LC	liquid coating
LC	load condition
LCA	life-cycle analysis
LCA	life-cycle assessment
LCB	long-chain branching
LCCM	liquid composite compression molding
LCD	liquid crystal display
LCD	lowest common denominator
LCI	life-cycle inventory
LCL	lower control unit
LCM	liquid composite molding
LCM	liquid curing medium (salt-bath vulcanization)
LCMP	lowest critical melting point
LCMS	liquid chromatography mass spectroscopy
LCP	layer control plate
LCP	liquid crystal polymer/plastic
LCP	lower cloud point
LCR	low crystallinity
LCT	liquid crystalline thermoset
LD	laser desorption
LD	laser disc
L/D	length-to-diameter (ratio)
LDEF	long duration exposure facility
LDF	long discontinuous fiber
LDI	laser direct image
LDM	light depolarization microscopy
LDPE	low-density polyethylene (also PE-LD)
LDR	linear dynamic range
LDV	laser doppler velocimetry
LEA	leather
LEC	liquid elastomer connector
LED	light emitting diode
LEED	low-energy electron diffraction
LF	lattice fluid
LF	long fiber
LFP	long-fiber prepreg
LGF	long glass fiber
LGL	low gloss
Li	lithium
Li-Fo	last in, first out
LI	linen
LI	flax
LIB	liquid isothermal (spinning) bath
LIF	laser-induced fluorescence
LIFT	lateral ignition flame spread test
LIL	linear elastic limit
LIM	liquid impingement molding (now called RIM)
LIM	liquid injection molding
LIMM	light intensity modulation method
LIMS	liquid injection-molding simulation
LIPN	latex interpenetrating polymer network
LIPP	laser-induced pressure pulse
LIS	laboratory integration system
LIS	large interactive surface
L-L	liquid-liquid
LLDPE	linear low-density polyethylene (also PE-LLD)
LLE	liquid-liquid equilibria
LLM	low-low modulus
lm	lumen
LM	lego molding
LMC	low-pressure molding compound
LMC	low molecular weight
LMDPE	linear medium density polyethylene
LMI	liquid metal infiltration
LMI	low migration
LMM	low molar mass
LMR	liquid molding resin
LMS	laser mass spectroscopy
LMW	low molecular weight
Ln	logarithm (natural)
LNG	liquefied natural gas
LNP	liquefied natural petroleum
LNR	liquid natural rubber
LNS	low notch sensitivity
LOD	limit of detection
LODP	leveling-off degree of polymerization
log	logarithm (common)
LOI	limiting oxygen index
LOI	loss on ignition
LOM	laminated object manufacturing
LOX	liquid oxygen
LP	liquid petroleum
LP	liquid polymer
LP	low pressure
LPA	low profile additive
LPD	low point displacement
LPE	linear polyethylene
LPET	linear polyethylene terephthalate
LPG	liquefied petroleum gas
LPG	low pressure gas
LPIM	low-pressure injection molding
LPMC	low-pressure molding compound
LPP	low-profile plastic
LPPP	low-pressure polymer precursor
LPR	liquid phase polymer retention
LPSF	low-pressure structural foam

LPT	linear position transducer
LRM	liquid reaction molding (now RIM)
LRP	latex reduction process
LRS	laser Raman spectroscopy
LS	light scattering
LS	light stabilizer
LS	low stabilizer
LS	low structure
LS	low shrink
LSC	liquid sieve chromatography
LSCE	liquid single crystal elastomer
LSE	low styrene emission
LSF	light scattering film
LSF	low smoke fume
LSP	laser sintering process
LSR	liquid silicone rubber
LSS	lap shear strength
LST	load-strain tangent
Ltd.	Limited
LTD	linear differential transformer
LTL	less truck load
LTP	low temperature polymerization
LUB	lubricate
LV	low viscosity
LVC	low volatile content
LVDT	linear variable differential transducer
LVDT	linear variable differential transformer
LVDT	linear velocity displacement transducer
LVDW	London-van der Waals forces
LVE	linear viscoelasticity
LVN	limiting viscosity number
LVO	low volatility
LW	low warpage
LWP	lost wax process
Lx	lux
m	matrix
m	metallocene (catalyst)
m	meter
mg	milligram
mμ	micromillimeter, millicron; 0.000001 mm
μm	micrometer (see also M_m)
M	mega
M	melamine, methyl, methylene, etc.
M	mega (prefix for 10^6)
M	mole
M	million
M	molar (actual mass)
M_b	bending moment
M_c	cross-linked density
M_c	molecular weight per cross-linked unit
M_c	network parameter
M_m	micrometer (see also μm)
M_n	number-average molecular weight
M_v	viscosity-average molecular weight
M_w	weight-average molecular weight
M_z	Z-average molecular weight
Ma	Manila hemp
MA	maleic acid
MA	maleic anhydride
MA	materials analyst
MAA	methacrylic acid
MABS	methylmethacrylate ABS
MAc	methyl acetate
MACT	maximum available control technology
MAD	mean absolute deviation
MAD	molding area diagram
MAH	methyl anhydride
MAI	methacrylyl isocyanate
MAN	methyl acrylonitrile
MAO	methyl aluminoxane
MAP	modified atmosphere packaging
MAP	manufacturing automation protocol
MAM	methyl acrylamide
MAPP	Mid-Atlantic Plastics Partners Inc.
MAR	mar resistance
MAT	matte finish
MAT	modified atmosphere packaging
max.	maximum
MB	masterbatch
MB	megabyte (million bytes)
MB	mercaptobenzimidazole
MBO	management buyout
MBP	modified bulk polymerization
MBS	methacrylic-butadiene-styrene copolymer
MBT	mercaptobenzthiazole
MBZ	zinc mercaptobenzthiazole
m/c	machine
MC	megacycle
MC	methyl cellulose
MC	moisture control
MC	motion control
MCA	Manufacturers' Association
MCB	monochlorobenzene
MCI	multicomponent injection
MCF	microcellular foam
MCl	methylene chloride
MCL	methyl caprolactam
MCM	modified compression molding
MCP	metallic cycling polymerization
MCS	motion control system
MCT	metallic-core technology
MD	machine direction
MD	market dynamic
MD	mean deviation
MDA	methylene dianiline
MDA	molecular density molding
MD&DI	Medical Device and Diagnostic Industry
MDD	Medical Devices Directory
MDE	maleic acid diester
MDG	machine data gathering

MDI	methylene-diphenylene diisocyanate
MDM	match die molding
MDO	machine-direction orienter
MDPE	medium density polyethylene (also PE-MD)
MDPM	mode dispersion phase matching
MDR	molecular draw ratio
MDR	moving die rheometer
MDSC	modulated differential scanning calorimetry
Me	metal ion
Me	metallocene catalyst
Me	methyl group
ME	mechanical engineer
ME	metal fiber
MEI	melt elasticity index
MEK	methyl ethyl ketone
MEKP	methyl ethyl ketone peroxide
MEL	maximum exposure limit
meq	milli-equivalent
MER	chemical repeating unit
MER	mechanical energy resolver
MES	manufacturing execution system
MF	main frame
MF	melamine formaldehyde
MF	melt fracture
MF	monofilament
MFA	melt-flow additive
MFA	multifunctional additive
MFD	micro floppy disc
MFD	mold fill direction
MFD	mold-flow direction
MFE	magnetic field effect
MFFT	minimum film forming temperature
MFG	molded fiberglass
mfgr.	manufacturing
MFI	melt-flow index (see MI)
MFN	melt-flow number
MFR	melt-flow rate
MFR	melt-mass flow rate
Mfrs.	manufacturers
MFV	melt front velocity
mg	milligram
Mg	magnesium
Mg	megagram
MG	milled glass
MGM	multigrain model (morphology)
MH	material handling
MH	microhardness
mHDPE	metallocene HDPE (different m/plastics such as mPS, mPP, etc.)
mi	mile
MI	melt index (see MFI)
MI	methyleneindane
MIB	methyl isobutyrate
MIC	mica
MID	molded interconnect device
mike	microinch (10^{-6} in.)
mil	one-thousand of inch (10^{-6} in.)
MIL	machine interface level
MIL	military
MIM	metal injection molding
MIM	mirror image method
MI/MO	multi-input/multi-output
min	minute
min.	minimum
MIN	mineral
MIPS	medium impact polystyrene
MIPS	millions of instructions per second
MIR	middle infrared
MIRS	multiple internal reflection spectroscopy
MIS	management information system
MIS	minimally invasive drudgery
misc.	miscellaneous
MIT	Massachusetts Institute of Technology
MITI	Ministry International Trade Association (Japan)
MIU	machine interface unit
MJ	megajoule
ml	milliliter
MLD	mildew resistance
MLFM	multilive feed molding
MLS	melt strength
mm	millimeter
MM	billion
MM	molecular mass
MMA	methyl methacrylate
MMC	metal matrix composite
MMC	monolithic metal composite
MMD	molecular mass distribution
MME	monomethyl ethanolamine
MMMF	manmade mineral fiber
MMFPA	Manmade Fiber Producers' Association
mmol	millimole
MMW	medium molecular weight
Mn	manganese
Mn	million
Mn	number average molecular weight
MNA	methyl nitroaniline
mN/d	milli-Newton per denier
mo.	month
Mo	mohair
Mo	molybdenum
MO	magnetic-optical (see also CD)
MO	molecular orbital
MOD	modacryl fiber
MODEM	modular/demodular
MOE	metal-on-elastomer
MOE	modulus of elasticity
mol	mole, molecule, or molecular
mol. wt.	molecular weight
MOR	modulus of rupture
MOS	membrane osmometry

MoS_2	molybdenum disulfide
MOT	management of technology
m.p.	melting point
MP	maintenance profession
MP	metal powder
MP	military police
MP	*Modern Plastics* magazine
MPa	mega-Pascal
MPA	modified polyamide
MPCP	molded printed circuit board
MPDA	M-phenylene diamine
MPE	mechanical packaging engineering
MPE	metallized polyester film
MPE	metallocene polyethylene
MPF	melamine-phenol-formaldehyde
mph	miles per hour
MPM	matched potential method
MPPO	modified PPO
MPR	melt-processable rubber
MPT	microcellular plastics technology
MPU	microcellular polyurethane
MQ	dimethylsilicone elastomer
MR	molar refraction
MR	mold resistant
MR	mold release
MRB	Malaysian Rubber Bureau
MRG	mechanical rubber group
MRI	magnetic resonance imaging
MRF	material recovery facility
MRO	maintenance-repair-operation
MRP	manufacturing requirement planning
MRP	materials requirement planning
MRPC	Malaysian Rubber Producers' Council
MRPL	manufactured recycled plastic lumber
MRPMA	Malaysian Rubber Products Manufacturers' Association
MRPP	Marco reinforced-plastic process
MRR	molecular reactivity ratio
MRT	mean residence time
MS	manuscript
MS	market strategy
MS	mass spectrometry
MS	molar substitution
MS	monocrystalline silicon
MS	*Molding Systems* magazine (of SME; previously called *Plastics World*)
MSA	mean optical approximation
MSD	mass selective detector
MSDS	material safety data sheet
MSF	melt spiral flow (test)
Msi	million pounds per square inch (psi $\times 10^6$)
MST	mechanical stability time
MST	moisture resistance
MST	magnetostrictive transducer
MSW	mocked-switch woven (reinforcement)
MSW	municipal solid waste
MSWI	municipal solid waste incineration
MT	metric ton
MtA	menthyl acrylate
MTBI	bismuth dimethyl dithiocarbamate
MTCE	melt transformation coextrusion
MTE	melt transformation extrusion
MTM	mixed tertiary mercaptan
Mtn	methanol (methyl alcohol)
MTO	melt temperature override
MTQ	management for total quality
MTST	minimum thermal stability temperature
MUD	Master Unit Die
MUF	melamine urea formaldehyde
MUP	Danish Materials Research Program
MUX	multiplexer (analog)
mV	millivolt
MV	melt velocity
MVD	molding volume diagram
MVE	methyl vinyl ether
MVI	melt-volume index
MVK	methyl vinyl ketone
MVP	Macro vacuum pressure
MVP	methyl vinyl pyridine
MVR	molding vapor resistance
MVS	metal vapor synthesis
MVSS	motor vehicle safety standard
MVT	moisture vapor transmission
MVTR	moisture vapor transmission rate
MVX	mixing venting extruder
MW	megawatt
MW	microwave
MW	molecular weight
MWD	molecular-weight distribution
MWR	microwave radiation
MWR	molding with rotation
N	mole fraction
N	Nano (10^{-9})
N	Newton (force)
N	nitrate, nonyl, etc.
N	normal (as applied to concentration)
N	number of cycles
N_2	nitrogen
Na	sodium
NA	not applicable
NA	numerical aperture
NA	not available
NAA	neutron activation analysis
NAA	sodium acrylate
NAAEE	North America Association for Environmental Education
NAAQS	National Ambient Air Quality Standards
NACE	National Association of Corrosion Engineers
NACO	National Association of CAD/CAM Operation

$NaCO_3$	sodium carbonate
NAD	nonaqueous dispersion
NAFTA	North America Free Trade Agreement
NAGS	North America Geosynthetics Society
NAO	nonasbestos organic
NaOH	sodium hydroxide
NAPCR	National Association for Plastics Container Recovery
NAPH	naphthenic (oil)
NaPSS	sodium polystyrene sulphonate
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NASL	number average sequence length
NATEC	National Technical Conference (SPE)
NB	nitrobenzene
NB	nonblooming
NBP	number branching points per molecule
NBR	nitrile-butadiene rubber (acrylonitrile-butadiene rubber)
NBS	National Bureau of Standards (since 1980s renamed National Institute of Standards and Technology or NIST)
NC	nitrocellulose (cellulose nitrate)
NC	numerical control
NCCA	National Coil Coaters Association
NCGA	National Computer Graphics Association
NCO	nitrogen carbon monoxide
NCP	National Certification in Plastics
NCR	acrylonitrile-chloroprene elastomer
NCR	National Cash Register
NCR	no carbon required
NCR	no carbon paper
NCRC	National Container Recycling Coalition
Nd	neodymium
ND	nondiscoloring
NDB	negative deviation behavior
NDE	nondestructive evaluation
NDI	naphthalene diisocyanate
NDI	nondestructive inspection
NDIR	nondispersive infrared
NDT	nondestructive testing
Ne	neon
NE	nitroethane
NEAT	nothing else added to it
NEBD	nonequilibrium Brownian dynamics
NEG	negative
NEMA	National Electrical Manufacturers' Association
NEN	Dutch standard
NFE	nonlinear finite element
NFK	Dutch Plastics Federation
NFPA	National Fire Protection Association
NFPA	National Food Processors' Association
NFRC	National Fenestration Rating Council
NFT	nutrient film technique
NG	natural gas
NG	next generation
NG	nitroglycerine
NG	no good
NGV	natural gas vehicle
NHI	no human involved
Ni	nickel
NIMCR	National Institute of Materials and Chemical Research
NIH	National Institute of Health
NIOSH	National Institute for Occupational Safety and Health
NIR	acrylonitrile isoprene rubber
NIR	near infrared
NIR	nitrile-isoprene rubber
NIST	National Institute of Standards and Technology (also see NBS)
NITSE	nonintermeshing twin-screw extruder
NLA	National Lime Association
NLO	net operating loss
NLO	nonlinear optical
nm	nanometer
NM	nitrometer
NMI	naphthyl maleimide
NMI	no middle initial
NMI	nuclear magnetic image
NMP	n-methyl-2-pyrrolidone
NMR	nuclear magnetic resonance
NMRI	nuclear magnetic resonance imaging
NMW	narrow molecular weight
NMWD	narrow molecular-weight distribution
No	nobelium
No.	number
NOL	Naval Ordnance Laboratory
NOL	no live operator
NOS	not otherwise specified
NOSE	nuisance odor solution evaluator
NOX	nitrogen oxide
NP	network polymer
NP	nitroproprene
NPC	nozzle pressure control
NPCM	National Plastics Center and Museum
NPE	National Plastics Exhibition (SPI)
NPFC	U.S. National Publications and Forms Center
NPII	National Printing Ink Institute
NPL	no plate-out
NPRC	National Polystyrene Recycling Co.
NQR	nuclear quadrupole resonance
NR	natural rubber (polyisoprene)
NR	neutron reflectometry
NRA	nuclear reaction analysis
NRC	National Recycling Coalition
NRC	National Research Council
NRCA	National Roofing Contractor's Association
NRDGA	National Retail Dry Goods Association

NRL	Naval Research Laboratory
NS	nonstaining
NSC	National Safety Council
NSDA	National Soft Drink Association
NSE	neutron spin-echo
NSF	National Sanitation Foundation
NSF	National Science Foundation
NSR	nitrile-silicone rubber
NST	nonstaining
NSWA	National Solid Waste Association
NT	natural
NTDRA	National Tire Dealers and Retreaders Association
NTIS	U.S. National Technical Information
NTMA	National Tool and Machining Association
NTTC	National Technology Transfer Center
NTX	nontoxic
NUC	nucleated
NURBS	nonuniform rational B-spline
NV	nonvolatile
NVH	noise-vibration-harshness
NVLAP	National Voluntary Laboratory Accreditation Program
NVV	nonvolatile by volume
NWPCA	National Wooden Pallet and Container Association
NXLPE	non-cross-linked polyethylene
nylon	(see PA)
Ω	ohm
O	octyl, oil, oxy, etc.
O	oriented
O	ortho
O−	oxygen denoting attachment
O_2	oxygen
O_3	ozone
OAD	organo-aluminum compound
OASIS	operational automated schedule information system
OC	operating characteristic
OCM	open-cell model
OCR	optical character recognition
OD	optical density
OD	optical disc (see also CD)
OD	outside diameter
ODC	ozone-depleting compound
ODD	optical data disc
ODF	orientation distribution function
ODG	operating data gathering
ODP	octyl decyl phthalate
ODP	ozone depletion potential
ODR	operational data recording
ODR	optical density ratio
ODR	oscillating disk rheometer
ODS	optical data storage
ODT	order-disorder transition
OE	oil extended
OE	original equipment
OE-EPDM	oil extended-ethylene-propylene diene monomer
OEI	one essential ingredient
OEL	occupational exposure limit
OEM	original equipment manufacturer
OEP	oil extended polymer
OES	occupational exposure standard
OES	optical emission spectroscopy
OF	oriented fiber
OFB	oscillatory flow birefringence
OFR	U.S. Office of Federal Register
OFS	organo-functional silane
OFT	orifice flow test
OH	oxygen-hydrogen
OHC	open-hole compression
OI	oxygen index
OIC	organic-inorganic composite
OIT	oxidative induction test
OJT	on-the-job training
OLB	online bidding
OLN	oleyl nitrile
OM	optical microscopy
OMBD	organic molecular beam deposition
OMD	open-mold deposit
ONON	organically modified montmorillonite
ONMR	optical nuclear magnetic resonance
ONR	U.S. Office of Naval Research
OP	optical property
OPE	oxidized polyethylene
OPEC	Organization of Petroleum Exporting Countries
OPET	oriented polyethylene terephthalate
OPEVAL	operational evaluation
OPLS	optimized potential for liquid simulation
OPO	optical parametric oscillator
OPP	oriented polypropylene
OPR	propylene oxide rubber
OPS	oriented polystyrene
OPVC	oriented polyvinyl chloride
OR	oil resistance
Orbet	oriented-blow extrusion technique (Phillips)
org	organic
org	original
org	organization
OS	osmometry
OSA	olefin-modified styrene-acrylonitrile
OSHA	U.S. Occupational Safety and Health Administration
OTC	over the counter
OTE	optical transparent electrically
OTL	out to lunch
OTLC	open tubular hydrodynamic chromatography
OTPE	olefinic thermoplastic elastomer
OTPV	olefinic thermoplastic vulcanizate

OTR	oxygen transmission rate
OTTLE	optically transparent thin layer electro-chemical
OVD	optical variable device
O/W	oil-in-water
OWF	on weight of fiber
OWG	on weight of goods
OWM	optical waveguide microscopy
Ox	oxide
OXR	oxidation resistance
oz	ounce
OZR	ozone resistance
%vol	percentage by volume (prefer vol%)
%wt	percentage by weight (prefer wt%)
μP	microprocessor
P	load
P	permeability
P	phenyl
P	phosphorus
P	poise
P	polymer
P	pressure
P	proportional
Pa	Pascal
PA	phthalic anhydride
PA	polyamide (nylon normally followed by number)
PA 610	Nylon 610 (one of various examples)
PAA	phosphoric acid anodized
PAA	polyacrylamide
PAA	polyacrylic acid
PAC	polyacetylene
PAC	polyacrylic
PADC	polyallyl diglycol carbonate (see also ADC)
PAE	polyarylether
PAEK	polyaryletherketone
PAEPO	polyarylene ether phosphine oxide
PAES	polyaryl ether sulphone
PAH	plycyclic aromatic hydrocarbon
PAI	polyamide-imide
PAK	polyester alkyd
PAM	modified acrylic fiber
PAM	polyacrylamide
PAMA	polyalkyl methacrylate
PAM/FM	pulse amplitude modulation/frequency modulation
PAMS	polyalpha-methylstyrene
PAN	polyacrylonitrile
PAN	polyaniline
PANI	polyaniline
PAO	primary antioxidant
PAPI	polyaryl polyisocyanate
PAR	polyarylate
Pa-s	Pascal second
PAS	polyarylsulphone
PAS	position-annihilation spectroscopy
PASA	polyamide-sulphonamide
PASS	polymer analysis and simulation software
PASU	polyarylsulfone
PAT	polyalkylthiophene
PAUR	polyester urethane
PAz	polyaxelaic acid
Pb	lead
PB	polybutadiene
PB	polybutylene
PB	proportional band
PBA	perfluorobutyric acid
PBA	physical blowing agent
PBA	Plastics Bag Association
PBA	polybenzamide
PBA	polybutyl acrylate
PBA	polybutylene adipate
PBAN	polybutylene-acrylonitrile
PBC	periodic boundary condition
PBCA	polybutylcyanoacrylate
PBD	polybutadiene
PBDE	polybrominated diphenylether
PBGAD	polybutylene glycol adipate
PBI	Plastics Bottle Institute
PBI	polybenzimidazole
PBIC	polybutylisocyanate
PBIP	polybutylene isophthalate
PBMS	probability-based matching system
PBMA	polybutyl methacrylate
PBMC	phenolic bulk-molding compound
PBN	polybutyl naphthalate
PbO	lead oxide
PBO	polybenzobisoxazole
PBO	prototyping by objectives
PBR	polybutadiene-vinyl pyridine
PBS	polybutadiene-styrene
PBT	polybutadiene-terephthalate
Pbu	polybutadiene
PBU	polybutadiene polyurethane
pbw	parts per weight
PBZ	polybenzobisoxazole
PC	paper chromatography
PC	permeability coefficient
PC	personal computer
PC	plastic composite
PC	plastic compounding
PC	plastic-concrete
PC	polyacrylonitrile
PC	polycarbonate
PC	polymer concrete
PC	positive collapse
PC	printed circuit
PC	process control
PC	programmable circuit
PC	programmable controller
PC	propylene carbonate
PCA	polycarbonate-acrylic
PCA	principal component analysis

PCB polychlorinated biphenyl
PCB printed circuit board
PCC polymer cement concrete
PCC precipitated calcium carbonate
PCD pacer cardioverter defibrillator
PCD polycarbodimide
PCDP polydicyclopentadiene
pcf pounds per cubic foot
PCF polychlorotrifluoroethylene
PCFC polychlorofluorocarbon
PCIA Personnel Communications Industry Association
PCL polycaprolactam
PCM phase contrast microscopy
PCMCA Personal Computer Memory Card Association
PCO polycarbonate
PCP polychloroprene
PC/PBT polycarbonate/polybutylene-terephthalate
PCR postconsumer recycled
PCR postconsumer resin
PCR principal component regression
PCS personal communication service
PCS photon correlation spectroscopy
PCS pollution control system
PCS polycarbosilane
PCS production control station
PCT Patent Cooperation Treaty
PCT polycyclohexylenedimethylene-terephthalate
PCTA CHDM-PTA copolyester
PCTFE polychlorotrifluoroethylene
PCTG glycol-modified PCT copolymer
PCV peroxide curing vulcanizate
PCZ polyvinyl carbazole
Pd palladium
PD plasma deposition
PDA production data acquisition
PDAP polydiallyl phthalate
PDAS photo data analysis system
PDB positive deviation behavior
PDCPD polydicyclopentadiene
PDES product data-exchange specification
PDF plastics design forum
PDFM *Plastics Distributors and Fabricators* magazine
PDHF polydihexylfluorene
PDS polydioxanone
PDT polymer decomposition temperature
PE photoelasticity
PE piezoelectric
PE plastics engineer
PE polyether
PE polyethylene
PE polythene
PE professional engineer
PEA polyethyl acrylate
PEA polyethylene adipate
PEB postexposure baking
PEBA polyether block amide
PEC chlorinated polyethylene (CPE)
PEC polyester carbonate
PEC polyphenylene ether copolymer
PECH polyepichlorohydrin
PE-CS polyethylene-chlorosulfonated
PEDT polyethylene dioxithiophene
PEE polyether ester
PEEC polyethylene ether carbonate
PEEK polyetheretherketone
PEEKK polyetheretherketoneketone
PEEL polyether elastomer
PEES polyetherether sulfone
PEG polyethylene glycol
PE-HD polyethylene-high density (see also HDPE)
PEI polyetherimide
PEI polyethylene imine
PEI polyethylene isophthalate
PEK polyetherketone
PEKEKK polyetherketoneetherketoneketone
PEKK polyaryletherketoneetherketone
PEKK polyetherketoneketone
PEL permissible exposure limit
PE-LD polyethylene-low density (see also LDPE)
PE-LLD polyethylene-linear low density (see also LLDPE)
PEMA polyethylmethacrylate
PE-MD polyethylene-medium density (also MDPE)
PEN polyethernitrile
PEN polyethylene naphthalate
PEO polyethylene oxide
PEP polyethylene polyamine
PEPA polyether-polyamide
PEPO polyarylene ether phosphine oxide
PER photoelastic relation
PES photoelectron spectroscopy
PES polyester
PES polyether sulfone
PES polysulphone
PESU polyethersulphone
Pet petroleum distillate
PET position emission tomography
PET polyethylene terephthalate
PETG polyethylene terephthalate glycol
PETG positron emission tomography
PETS plastics evaluation and troubleshooting system
PEU polyether urethane
PE-UHMW ultra-high molecular weight polyethylene (or UHMWPE)
PEUR polyether urethane
PEX cross-linked polyethylene (or XLPE)
PF phenol formaldehyde (phenolic)

PFA	perfluoroalkoxy alkane
PFA	pulverized fuel ash
PFB	perfluorobenzene
PFF	phenol furfural
PFFC	*Paper, Film, and Converter* magazine
PFI	perfluorinated ionomer
PFM	polymeric flow model
PFP	phenolic foam plastics
PFT	plastics fuel tank
PG	propylene glycol
PGE	planetary gear extruder
pH	hydrogen ion exponent
pH	negative logarithm of hydrogen
PHA	polyhydroxyamine
PHB	photochemical hole burning (spectroscope)
PHB	polyhydroxybutyrate
PHE	parts handling equipment
PHEN	phenoxy
phr	parts per hundred
PHR	peak heat release
pi	$\pi = 3.141593$
PI	isoprene rubber
PI	paper
PI	polyimide
PI	proportional integral
PIA	Plastics Institute of America
PIB	polyisobutylene
PIB	polyisobutene
PIBI	polyisobutylene-isoptene (butyl rubber)
PIC	polymer impregnated concrete
PID	proportional-integral-derivative
PIE	polyisobutylene
PIM	phenylpolyimine
PIM	powder injection molding
PIM	pulse injection molding
PIP	product improvement program
PIP	pure internal pressure
PIPA	polyisophthalamide
PIR	polyisocyanurate
PIRG	public-interest research group
PIRRG	Plastics Industry Risk Retention Group (insurance)
PIS	polyisobutylene
PISU	polyimidesulfone
PISX	polyimidesilozane
PITA	parison inflation thinning analysis
PK	polycarbonate
PK	polyketone
PKG	packaging grade
PL	parting line
PL	plate-out
PL	polyethylene (usually PE)
PLA	polyactic acid
PLASTEC	Plastics Technical Evaluation Center (U.S. Army)
PLB	picture level benchmark
PLC	programmable logic controller
PLF	polymer fiber
PLM	polarized light microscopy
PLS	plasma spray
PLS	plasticize
PLT	platable
PLTA	Plastics Lumber Trade Association
PM	polarized microscopy
PM	polymeric matrix
PM	polymethylene
PM	powder metallurgy
PM	preventative maintenance
PMA	polymethyl acrylate
PMA	premarket approval
PMA	Polyurethane Manufacturers' Association
PMAN	polymethyl-acrylonitrile
PMC	polyester molding compound
PMC	powder mold coating
PMCA	polymethyl-chloroacrylate
PMDI	polymeric methylene diphenylene diisocyanate
PMI	polymethacrylimide
PML	plastic multilayer
PMMA	Plastics Molders and Manufacturers' Association (of SME)
PMMA	polymethyl methacrylate (acrylic)
PMMI	Packaging Machinery Manufacturers' Institute
PMN	premanufacturing notice
PMO	polymethylene oxide
PMP	polymethyl pentene
PMQ	phenylsilicone elastomer
PMR	polymerization monomer reactant
PMR	proton magnetic resonance
PMS	paramethyl styrene
PMT	polymer melting temperature
PMT	polymethylpentene
PMV	point of minimum viscosity
PNC	puncture resistance
PNF	phosphorus nitrile
PNF	polyfluoroalkoxyphosphazene
PNT	paintable
PO	phenoxy
PO	photooxidation
PO	polyolefin
PO	polypropylene oxide
PO	U.S. Post Office
PO	pull-out strength
POD	polyoxyadiazol
POE	polyolefin elastomer
POF	plastic optical fiber
POL	polymer
PO	procedure-oriented language
POLY	polyol
POM	polyacetal
POM	polyoxymethylene (acetal)

POP	point of purchase
POP	polyolefin plastomer
POP	polyoxypropylene
POP	polyphenylene oxide
POR	pourable
POS	polyorganophosphazene
POS	positive
PP	piperidine
PP	polypropylene
PP	press-blowing
PPA	Plastics Pioneer Association
PPA	Polymer Processors' Association
PPA	polyphthalamide
ppb	parts per billion
PPC	chlorinate polypropylene (also CPP)
PPC	production planning and control
PPC	propylene chlorinated
PPC	Polystyrene Packaging Council
PPC	Paperboard Packaging Council
PPCC	plastic Portland cement concrete
PPD	paraphenylene diamine
PPDF	plastics product designers' forum
PPE	polyphenylene ether
PPh	polyphosphate
PPI	polymeric isocyanate
PPO	polyphenylene oxide
PPFA	Plastics Pipe and Fittings Association
pph	parts per hour
PPI	Plastics Pipe Institute (SPI)
PPI	polymeric polyisocyanate
PPI	Polymer Processing Institute
ppm	parts per million
ppm	parts per minute
PPMA	polypropylene methacrylate
PPMS	polypara-methylstyrene
PPO	polyphenylene oxide
PPOX	polypropylene oxide
PPP	Partnership for Plastics Progress (changed to APC)
PPP	polyparaphenylene
ppb	parts per billion
PPS	Polymer Processing Society
PPS	polyphenylene sulfide
PPSS	polyphenylene sulfide sulfone
PPSU	polyphenylene sulfone
PPT	polypropylene terephthalate
PPT	precipitate
PPTA	polyphenylene terephthalate
PPTN	precipitation
PPV	polyphenylenevinylene
PPVC	plasticized polyvinyl chloride
PPX	poly(P-xylylene)
PPY	polyacetylene-polypyrrole
PPZ	polyorgananophosphazene
PQ	polyquinoline
PR	personal representative
PR	plastics recycling
PR	press release
PR	proprietary
PR	pump ratio
PRC	plastic reinforced concrete
PRF	Plastics Recycling Foundation
PRI	Plastic and Rubber Institute
PRM	plastic reflective material
PRN	printable
Pro	propane
PRO	proline
PRRC	Polyurethane Recycle and Recovery Council
PRO	product requirements optimization
PROM	programmable read-only memory
PRT	pressure reduction time
PRT	product reliability test
ps	postscript
PS	polystyrene
PS	polysulphone
PS	power supply
PS	problem solving
PS	public school
P/S	pressure sensitive adhesive
PSA	polysebacic acid
PSA	pressure sensitive adhesive
PSB	polystyrene butadiene rubber (GR-S, SBR)
PSC	point stress criterion
PSD	particle size distribution
PSE	polystyrene-ethylene copolymer
psf	pounds per square foot
PS-F	polystyrene-foam
PSF	polysulphone
psi	pounds per square inch
psia	pounds per square inch, absolute
psid	pounds per square inch, differential
psig	pounds per square inch, gauge (above atmospheric pressure)
PSL	polystyrene latex
PSMC	phenolic sheet molding compound
PSO	polysulfone
PSPC	Polystyrene Packaging Council
PSS	polystyrene sulphonate
PSU	polysulphone
Pt	platinum
PT	phenyl tetrazine
PT	physical therapy
PT	*Plastics Technology* magazine
PT	polythiophene
P-T	pressure-temperature
PTA	phthalic anhydride
PTA	purified terephthalic acid
PTE	patent term expansion
PTFE	polytetrafluoroethylene (TFE)
PTMG	polytetramethylene glycol

PTMT	polytetramethylene-terephthalate
PTO	U.S. Patent and Trademark Office
PTX	pressure-temperature concentration variables
Pu	plutonium
PU	polyurethane
Publ.	publication
PUE	polyurethane elastomer
PUF	polyurethane foam
Pul	pultrusion
PUR	polyurethane (also PU, UP)
p.v.	pore volume
P-V	pressure-volume (also PV)
PV	process validation
PVA	polyvinyl acetate
PVAB	polyvinyl acetal butyral
PVAC	polyvinyl acetate
PVAL	polyvinyl alcohol (PVOH)
PVB	polyvinyl butyral
PVC	polyvinyl chloride
PVCA	polyvinyl chloride acetate
PVCH	polyvinylcyclohezane
PVCL	polyvinyl caprolactam
PVCZ	polyvinyl carbazole
PVD	physical vapor deposition
PVDA	polyvinylidene acetate
PVDC	polyvinylidene chloride
PVDF	polyvinylidene fluoride
PVEE	polyvinyl ether ether
PVF	polyvinyl fluoride
PVF	polyvinyl formal
PVFM	polyvinyl formal
PVIE	polyvinyl isobutyl ether
PVI	polyvinylimidazole
PVK	polyvinyl carbazole
PVOH	polyvinyl alcohol (PVAL)
PVP	polyvinyl pyrrolidone
PVPO	polyvinyl pyrroldone plastic
PVS	post vulcanization stabilizer
PVT	pressure-volume-temperature (also P-V-T or pvT)
PW	*Plastics World* magazine (in 1997 became *Molding Systems* of SME)
PWA	phosphotungstic acid
PWB	printed wiring board
PWD	powder
PXE	polyxylenyl ether
Py	pyrolysis
PZT	lead zirconate titanate

Q	quote
Q	silicone elastomer
QA	quality assurance
QA	quality auditing
Q+A	question+answer
QC	quality control
QCS	quick change system
QDS	quality data statistics
QF	quality factor
QM	quality management
QMC	quick material change
QMC	quick mold change
QPL	qualified products list
QSR	quality system regulation
QUAL	qualitative
Quan.	quantitative
q.v.	quod vide; which is

R	radius
R	Rankine
R	Reaumur
R	Rockwell (hardness)
R	Roentgen
R	roving
R&D	research and development
R&M	reliability and maintainability
Ra	radium
Ra	ramie (RA)
RA	reduction of area
RA	regulatory agency
RA	release agent
RA	resin acid
RA	risk assessment
RAB	registration accreditation board
RAC	Recycling Advisory Council
rad	radian
RAD	radiation resistance
radome	radar dome
RAF	random access file
RAIR	reflection angle infrared spectroscopy
RAM	radar absorbent material
RAM	random access memory
RAPRA	Rubber and Plastics Research Association
RAS	reflection absorption spectroscopy
RBA	Reserve Bank of Australia
RC	resistance condenser
RCA	Radio Corporation of America
RCA	Recycling Advisory Council
RCE	return on capital employed
RCF	refractory ceramic fiber
RCM	reaction compression molding
RCO	random-copolymer
RCP	rapid crack propagation
RCPS	rigid cellular polystyrene
RCR	reciprocating screw rheometer
RCRA	Resource Conservation and Recovery Act
RCY	recycled resin content
RD	redried
RDA	recommended dietary allowance
RDF	refuse-derived fuel
RDS	rheometric dynamic scanning
Re	Reynolds number

REE	rare earth element
Ref.	reference
Res	resorcinol
resp.	respectively
RETEC	regional technical conference (SPE)
REX	reactive extrusion
RF	radio frequency
RF	refrigeration grade
RF	resorcinol formaldehyde
RF	risk factor
RFI	radio frequency interference
RFM	resin flow molding
RFQ	request for quote
RG	radius of gyration
RGA	residual gas analysis
RGC	reverse gas chromatography
RGP	rigid gas-permeable
r.h.	relative humidity
RH	relative humidity
RHB	reheat blow
RHC	rubber hydrocarbon content
RHDPE	recycled high density polyethylene
RHE	rheometry
RHR	rate of heat release
RI	refractive index
RIA	radio immune assay
RIA	Robotic Industries' Association
RIE	reactive ion etching
RIM	reaction injection molding
RIP	rapid isothermal processing
RIS	rotational isometric state
RISC	reduced instruction set computing
RISD	Rhode Island School of Design
RLM	reactive liquid polymer
RLT	reverse laminate theory
RM	raw material
RM	rotational molding
RMA	relaxation map analysis
RMA	Rubber Manufacturers' Association
RMB	resorcinol monobenzoate
RMPS	rubber modified polystyrene
RMS	root mean square
RMSD	root mean square difference
RO	radiation oxidation
RO	reverse osmosis
ROA	Raman optical cavity
ROI	reactive oxygen intermediate
ROI	return on investment
ROM	read-only memory
ROM	rule of mixtures
RonD	research on design
ROPP	roll-on-pilfer-proof
ROR	rheometric on-line rheometer
RP	rapid prototyping
RP	reinforced plastic
RP	reverse phase
RP	risk probability
RPA	rubber peptizing agent
RPB	reactive polymer blending
RPBT	reinforced polybutylene terephthalate
RP/C	reinforced plastics/composites
RP/CI	reinforced plastics/Composites Institute (SPI)
RPD	relative positive deviation
RPET	recycled polyethylene terephthalate
RPET	reinforced polyethylene terephthalate
RPI	Rensselaer Polytechnic Institute
rpm	revolutions per minute
RPMP	reinforced plastic Marco process
RPRA	Rubber and Plastics Research Association
rps	revolutions per second
RPVC	rigid polyvinyl chloride
RRA	Risk Retention Act
RRIM	reinforced reaction injection molding
RS	Raman spectroscopy
RS	reciprocating screw
RSD	relative standard deviation
Rsec	reciprocal second
RSM	reaction spray molding
RSP	reciprocating screw plasticator
RT	rapid tooling
RT	real time
RT	residence time
RT	room temperature
RTA	rapid thermal annealing
RTC	room temperature cure
RTD	resistance temperature detector
RTD	residence time distribution
RTD	room temperature dry
RTI	relative thermal index
RTL	relaxation transition temperature
RTM	registered trademark
RTM	resin transfer molding
RTOS	real time operating system
RTP	reinforced thermoplastic
RTPO	reactor-made thermoplastic polyolefin
RTS	reinforced thermoset
RTV	room temperature vulcanization
RTW	room temperature wet
RUB	rubber
RUC	chlorinated rubber
RUF	rigid urethane foam
RV	repeatable/versatile
RVE	representative volume element
Rx	radiation cross-linking
Rx	radiation curing
s	second
S	Siemans
S	styrene
S	sulphur
S&DA	steel and dimensional analysis

SA	salt acid
SA	sebacic acid
SA	shrink allowance
SA	stearic acid
SA	styrene acrylate
SACMA	Suppliers and Advanced Composite Materials' Association
SAD	seasonal affective disorder
SAE	Society of Automotive Engineers
SAG	styrene-acrylonitrile-glycidyl
SAH	Shore A hardness
SAM	scanning acoustic microscopy
SAMPE	Society of the Advancement of Material and Process Engineers
SAN	styrene-acrylonitrile
SANS	small-angle neutron scattering
SAP	superabsorbent plastic
SAR	simulated acid rain
SARA	Superfund Amendments and Reauthorization Act
SAS	Saudi Arabian Standard
satd.	saturated
Sb	antimony
SB	styrene-butadiene
SBB	styrene-butadiene block
SBC	styrene block copolymer
SBM	stretch blow molding
SBR	styrene-butadiene rubber (also GRS)
SBS	short beam shear
SBS	styrene-butadiene-styrene
SC	surface coating
SCB	short cantilever beam
scf	standard cubic foot (760 mm Hg, °C)
scfm	standard cubic foot per minute
SCI	Society of Chemical Industry
SCM	solid-core model
SCORIM	shear controlled orientation of reinforcement in injection molding
SCORTEC	shear controlled orientation technology
SCR	silicon-controlled rectifier
SCR	styrene chloroprene rubber
SCS	scientific certificate system
SCT	soluble-core technology
SD	specific dispersion
SD	styrene derivative
SDM	standard deviation measurement
SDP	standard depth of penetration
SDM	standard deviation measurement
SDR	standard dimension ratio
SDWA	Safe Drinking Water Act
SE	shielding effect
SE	sound emission
SE	static electricity
sec	second
SEC	size extrusion chromatography
SED	sedimentation
SED	strain energy density
SEM	scanning electron microscope
SEP	styrene-ethylene-propylene
S-EPDM	sulfonated-EDPM
SETRAF	safety of enclosure for toxics using recirculated filtration
SF	safety factor
SF	scrapless forming
SF	shape factor
SF	short fiber
SF	structural foam
SFM	specific failure moment
SFM	structural foam molding
SFP	scrapless forming process
s.g.	specific gravity (SG)
SGF	short glass fiber
SGMP	statistical good manufacturing practices
SHED	sealed housing for evaporative determination
SHI-PP	superhigh-impact polypropylene
SHIPS	superhigh-impact polystyrene
Si	silicon
Si	sisal (SI)
SI	International System of Units
SI	silicone
SI	swelling index
SIC	Standard Industrial Classification
SIC	strain-induced crystallization
SIE	styrene-isoprene
SINEH	sine hyperbolic
SiO	silicon oxide (silica)
SiO_2	silicon dioxide
SIPN	sequential interpenetrating polymer network
SIR	silicone isoprene rubber
SIR	solvent impregnated resin
SIR	styrene-isoprene
SIRC	Styrene Information and Research Center
SIS	sisal
SIS	styrene-isoprene-styrene
SKB	butadiene rubber
SL	self-lubricating
SLA	stereolithography apparatus
SLCP	superstrong liquid crystal polymer (or plastic)
SLF	slit film
SLS	static light scattering
SLS	selective laser sintering
SLS	stereolithography contour
SLA	serviceability limit state
SM	shuttle mold
SM	slush molding
SM	styrene monomer
SM	sulphur mustard
SMA	styrene maleic anhydride
SMC	sheet-molding compound

SMCAA	Sheet Molding Compound Automotive Alliance
SMC-II	SMC, low-pressure molding
SMC-C	SMC-continuous fibers
SMC-D	SMC, directionally oriented
SMC-R	SMC, randomly oriented
SMC-S	SMC, structural
SME	Society of Manufacturing Engineers
S/MMA	styrene/methyl methylacrylate
SMR	surface modified rubber
SMS	styrene methylstyrene
SMT	surface mounted technology
S-N	stress-number of cycles
SN	synthetic natural rubber
Sn	tin
SNAP	significant new alternatives policy
SNR	signal-to-noise ratio
SNR	Standard Natural Rubber
SO	secondary operation
SOC	stress-optical coefficient
sol.	soluble
SOL	solvent resistance
SOS	self-opening style (bag)
SOS	silicon-on-sapphire
SP	saturated polyester
SP	softening point
SP	solubility parameter
Sp.	specific
SPC	statistical process control
SPE	Society of Plastics Engineers
SPE	solid-phase extraction
Spec.	specification
SPF	solid-phase forming
SPF	solid-plastic forming (Dow Chemical)
SPF	superplastic forming
SPF/DB	superplastic forming/diffusion bonding
sp. gr.	specific gravity
SPI	Society of the Plastics Industry
SPIE	Society of Photo-Optical Instrumentation Engineers
spm	stroke per minute
SPM	scanning potential microscope
sPP	syndiotactic polypropylene (SPP)
SPS	sulphonated polystyrene
SPS	syndiotactic polystyrene (sPS)
sp. vol.	specific volume
sq.	square
SQC	statistical quality control
sq. cm	square centimeter
sq. m	square meter
SR	polysulfide rubber
Sr	steradian (solid angle quantity)
Sr	strontium
SR	sink-mark resistance
SR	synthetic rubber
SRI	Standards Research Institute (ASTM)
SRIM	structural reaction injection molding
SRM	standard reference manual
SRP	styrene-rubber plastic
SRPE	solid redox polymerization electrode
ss	stainless steel
SS	single screw
SS	single source
SS	single stage
SS	stainless steel
S-S	stress-strain
SSE	solid-state extrusion
SSMC	single-site metallocene catalyst
SST	self-staining tape
SST	step-by-step test
SST	sulphonated styrene
SSTP	sheet stampable thermoplastic
SSWMC	Southern States Waste Management Coalition
ST	polythioglycol ether
ST	staining
ST	styrene
STAT	sheet thinning analysis of thermoforming
STC	stampable thermoplastic composite
STC	structural thermoplastic composite
STD	standard
STF	steel fiber
STL	stereolithography
STM	scanning tunneling microscopy
STP	Special Technical Publication (ASTM)
STP	standard temperature and pressure
S-twist	twisting fiber direction
STY	styrene
SU	spray up
SU	strain unit
Sv	sievert
SVA	styrene-vinyl acrylonitrile
SVK	Siemens shrinkage specimen
SWCC	Solid Waste Composing Council
SWF	stress wave factor
SWM	solid-waste management
t	thickness
T	temperature
T	tesla
T	time
T	toluene
T	torque (or T_t)
T	transverse direction (TD)
T_g	glass transition temperature
T_h	homogeneous temperature
T_m	melt temperature
T_s	specula transmission
T_s	tensile strength
T_s	temperature, brittle
T_s	temperature, softening
T&E	test and evaluation

Ta	annealing temperature
Ta	tantalum
TA	cellulose triacetate
TA	terephthalic acid
TA	thermal analysis
TA	thermoanalytical
TA	trend analysis
TAC	total area coverage
TAC	triallyl cyanurate
TAIC	triallyl isocyanurate
TAL	talc
TAM	triallyl trimellitate
TAM	thermal acoustic measurement
TAP	triallyl phosphate
TAPPI	Technical Association of the Pulp and Paper Industry
TB	terebyte (10^{12} bytes)
TC	temperature control
TC	thermal conductivity
TC	toxicity characteristic
T/C	thermocouple
TCA	thermal conductivity analysis
TCE	trichloroethylene
TCEF	trichloroethyl phosphate
TCF	tricresyl phosphate
TCI	thermochemical instability
TLCP	toxicity characteristic and leaching procedure
TCM	technical cost modeling
TCNA	Tube Council of America
TCNE	tetracyanoethylene
TCP	tricresyl phosphate
TCR	thermal cracking resistance
TD	thermal diffusivity
TD	transverse direction
TDA	Titanium Development Association
TDA	toluene diamine
TDI	methylphenylene diisocyanate
TDI	toluene diisocyanate
TDI	Tool and Die Institute (see TMA)
TDT	thermal decomposition temperature
TE	thermal expansion
TE	transfer efficiency
TEC	thermal expansion coefficient
TEC	triethyl citrate
TEEE	thermoplastic elastomer etherether
TEFE	tetrafluoroethylene
TEM	thermal electrical measurement
TEM	transmission electron microscopy
TEN	tensile strength (usually T_S)
TEO	thermoplastic elastomer olefinic
TEP	thermoelastoplastic
TEP	triethyl phosphate
TERA	(see tera in alphabetical listings)
TES	thermal energy storage
TES	thermoplastic elastomer-styrene
TETA	triethyltramine
TF	thermoformable
TFE	tetrafluoroethylene (PTFE)
TG	thermogravimetry
TG	thin gauge
TGA	thermogravimetric analysis
TGI	thermogravimetric index
THF	tetrahydrofuran
THK	thickened
THR	thermal stability
THR	total heat release
three-D	three-dimensional (3D)
Ti	titanium
TiALN	titanium aluminum nitride
TiCN	titanium carbonitride
TiN	titanium nitride
TiO_2	titanium dioxide
TIC	total ion content
TIR	technical information release
TIR	tooling indicator runout
TIR	total indicator reading
TIR	total internal reflection
TKP	tricresyl phosphate
TL	thermo-luminescence
T/L	truck load
TLC	thin-layer chromatography
TPCP	thermoplastic liquid crystal polymer/plastic
TLMI	Tag and Label Manufacturers' Institute
TLn	toluene (toluol)
TLV	threshold limit value
TM	thioplasts
TM	trademark
TM	transfer molding
TMA	thermomechanical analysis
TMA	Tooling and Manufacturing Association (formerly TDI)
TMC	temperature modulated calorimetry
TMC	thick molding compound
TMC	titanium-matrix composite
TMC	total machine control
TMC	trimethylene carbonate
TMM	thermal mechanical measurement
TMM	trimethylene methane
TMPTMA	trimethylolpropane trimethacrylate
TMU	tetramethyl urea
T/N	terephthalate/naphthalate
TN	trade name
TNR	term not recommended
TOC	tangliabue open cup (flash point)
TOC	total organic carbon
TOF	trioctyl phosphate
TOL	toluene
TOM	thermal optical measurement
TOP	trioctyl phosphate
torr	mm mercury (mmHg)

TOSCA	Toxic Substance Control Act
TOT	Toys of Tomorrow
TP	thermophotometry
TP	thermoplastic
TPA	terephthalic acid
TPC	thermoplastic composite
TPC	transfer point control
TPE	thermoplastic elastomer
TPEA	thermoplastic elastomer alloy
TPE-A	thermoplastic elastomer-amide
TPEE	thermoplastic elastomer-polyester
TPE-O	thermoplastic elastomer-olefin (or TPO)
TPI	thermoplastic polyimide
tpi	turns per inch
TPO	thermoplastic olefin (or TPE-O)
TPO	Trade and Professional Organizations
TPP	triphenyl phosphate
TPR	thermoplastic rubber
TPS	thermal protection system
TPS	toughened polystyrene
TPU	thermoplastic urethane (PU, PUR, TPUR)
TPV	thermoplastic vulcanizate
TPX	polymethyl pentene
TQC	total quality control
TQM	total quality management
TR	torque rheometer
TRE	thermoplastic reinforced elastomer
TREF	temperature rising elution fraction
TRK	tracking resistance
TRL	translucent
TRP	transparent
TRS	tear strength
TS	thermal sampling
TS	thermal setting
TS	thermoset
TS	three-stage
TS	three-step
TS	total solids
TS	troubleshooting
TS	twin-screw
TSC	thermal spray coating
TSC	thermal stimulated current
TSC	thermal stress cracking
TSCA	Toxic Substance Control Act
TSE	thermoset elastomer
TSE	twin-screw extruder
TSF	twin-sheet forming
TSI	thermoset polyimide
TSR	thermoset rubber
TSS	telecommunication switching system
TSSC	toluenesulfonyl semicarbazide
TSUR	thermoset polyurethane
TTT	time-temperature-transformation
TTU	through-transmission ultrasonic
TV	television
TVA	thermovolatilization analysis
TVL	tenth-value layer
TWA	technical working area
TWA	time-weighted average
two-D	two-dimensional (2D)
TX	thixotropic
Tx	toxic

U	uranium
UA	urea, unsaturated
UCL	upper confidence limit
UCL	upper control limit
UD	unidirectional
UDF	unidirectional fiber
UE	usability engineering
UF	ultrafiltration
UF	urea formaldehyde
UHM	ultrahigh modulus
UHMPE	ultrahigh modulus polyethylene
UHMW	ultrahigh molecular weight
UHMWPE	ultrahigh molecular weight polyethylene (or PE-UHMW)
UHV	ultrahigh vacuum
UL	Underwriters' Laboratories
ULDPE	ultralow-density polyethylene (or PE-ULD)
ULS	ultimate limit state
UM	University of Massachusetts (at different locations such as Lowell, UM-L)
UN	United Nations
UO	unioriented
UP	polyurethane (or PUR, UR)
UP	unsaturated polyester (TS)
UPC	uniform product code
UPR	unsaturated polyester resin
UPVC	unplasticized PVC
UR	urethane (also PUR, PU)
USA	United States of America (also U.S.A.)
USASI	USA Standards Institute
USBM	U.S. Bureau of Mines
USCAR	U.S. Council for Automotive Research
USP	unique selling price
USP	U.S. pharmacopoeia
USPO	U.S. Patent Office
USPO	U.S. Post Office
UT	unidirectional tape
UT	universal time
UTL	use temperature limit
UTS	ultimate tensile strength
UV	ultraviolet
UVA	ultraviolet absorber
UVC	ultraviolet curable
UVI	ultraviolet inhibitor

UVL	ultraviolet light
UVR	ultraviolet resistance
V	vacuum
V	vanadium
V	velocity
V	vinyl
V	volt
VA	value analysis (VAC)
VA	vinyl acetate
VAE	vinyl acetate ethylene
VAM	vacuum-assist molding
VARI	vacuum-assist resin injection
VAT	value-added tax
VB	vented barrel
VBM	vacuum bag molding
VC	vacuum casting
VC	vacuum coating
VC	vacuum control
VC	value creation
VC	vinyl chloride (VCM)
VC	virtually cross-linked
VCA	vinylene carbonate
VCA	vinylidene chloride-acrylonitrile
VCE	vinyl chloride-ethylene
VCEMA	vinyl chloride-ethylene-methyl acrylate
VCEV	vinyl chloride-ethylene-vinyl acetate
VCI	volatile corrosion inhibitor
VCM	vinyl chloride monomer
VC/MA	vinyl chloride/methylacrylate
VCMMA	vinyl chloride/methyl methacrylate
VCOA	vinyl chloride-octyl/acrylate
vcp	vacuum condensing point
VCR	volume compression ratio
VD	vacuum deposition
VD	vacuum distillation
VD	vinylidene
VDA	Association of the Automotive Industry (Germany)
VDC	vacuum deposition coating
VDC	vinylidene chloride
VDI	Verein Deutscheringenieure (Society of German Engineers)
VDP	vapor deposition polymerized
VDT	video display terminal
VDT	visual display tube
VDU	visual display unit (TV display)
VE	vented extruder
VE	vinyl ester
VERC	Vinyl Environmental Resource Center
VF	vacuum flashing
VF	vacuum forming
VF	vinyl fluoride
VF	vinylidene fluoride
VF	vulcanized fiber
VFC	voltage frequency converter
VG	valve gate
VHI	vapor hazard index
VHP	vacuum hot pressing
VI	vacuum impregnation
VI	Vinyl Institute
VI	viscose
VIM	vacuum injection molding
VIP	vertical ionization potential
VIS	absolute viscosity
VIS	visible-spectra
VL/C	vacuum loader/conveyor
VLC	vapor-liquid chromatography
VLDPE	very-low-density polyethylene (or PE-VLD)
VLM	very low modulus
VLS	vapor-liquid-solid (process)
VM	vacuum metallizing
VMC	vacuum mold cooling
VMQ	vinylsilicone elastomer
VOC	volatile organic compound
vol	volume
vol%	percentage by volume
VP	vacuum press
VP	virgin plastic
VPE	vulcanized polyethylene
VPI	vapor phase inhibitor
VPM	vacuum-press molding
VPT	velocity-pressure-transfer or velocity-pressure-transducer
VPTP	velocity-pressure-transfer point
VR	virtual reality (software)
VR	viscosity ratio
VR	volume resistivity
VR	vulcanized rubber
VRP	Vehicle Recycling Partnership
vs.	versus
VSI	Vinyl Siding Institute
VST	Vicat softening temperature
VT	Vicat temperature
VT	vinyl toluene
VUV	vacuum ultraviolet
w	width
W	tungsten
W	watt
WAD	worst area difference
WADC	weighted-average deformation characteristic
WAG	wild-ass guess
WB	webber
WC	tungsten carbide
WCA	water contact angle
WCM	world-class manufacturing
WF	wood flour
WF	woven fabric
WFT	wet film thickness
WH	whisker
WJ	water jet

WLD	weldable
WLF	Washington Legal Foundation
WLU	wet lay-up
Wo	wool
WP	word processing
WP&RT	*World Plastics and Rubber Technology* magazine
WPC	wood-plastic composite
WPC	world product code
WPE	Western Plastics Exhibition
WPI	wood-plastic impregnated
WPI	world Patent index
WR	woven roving
WRDC	Wright Research and Development Center
WS	water solubility
WS	workstation
WSB	water soluble polyester
wt	weight
wt%	percentage by weight
WTD	waiting time distribution
WTE	waste-to-energy
WTO	World Trade Organization
WVT	water vapor transmission
WVTR	water vapor transmission rate
W-W	win-win
WW	world war
WWW	World Wide Web
WYSIWYG	what you see is what you get
X	cross-linking ratio
X	number of structural units in a polymer molecule
X	arithmetic mean
X_m	number-average degree of polymerization
X_w	weight-average degree of polymerization
x-axis	axis in plane used as 0° reference
XAR	cross-linked acrylate
Xc	degree of crystallinity
Xe	xenon
XF	xylene formaldehyde
XL	cross-linked
XLA	xylylene amine
XLD	cross-link density
XLPE	cross-linked polyethylene
XMA	x-ray microanalysis
XMC	extra-high-strength molding compound
XPS	expandable polystyrene
XPS	expert system
XPS	extruded polystyrene
XPS	x-ray photoelectron spectroscope
XRD	x-ray diffraction
XRF	x-ray fluorescence
XRSD	x-ray scanning diffractography
XTC	RP mat with extra strength fibers
XXX	triple pressed
Xyl	xylene
y-axis	axis in the plane perpendicular to x-axis
Y2K	year 2000
YI	yellowness index
YIR	thermoplastic isoprene rubber
YPBO	polyether ester
YPE	yield point elongation
YQI	yarn quality index
yr	year
Z	atomic number (at. no.)
Z	rubber base
Z	zeta
Z	azelate
z-axis	axis normal to the plane of the x-y axes
ZBD	zinc dibenzyl dithocarbamate
ZBX	zinc dibutyl xanthate
ZD	zero defect
ZDP	zero defect product
ZDP	zinc dithiophosphate
ZHS	zinc hydroxystannate
ZIF	zero insertion force
ZIX	zinc isopropyl xanthate
ZMC	low viscosity molding compound
ZMS	zero metering screw
Zn	zinc
Z-N	Ziegler-Natta (ZN)
ZnAc	zinc acetate
ZNC	Ziegler-Natta catalyst
ZnSt	zinc stearate
ZnTPP	zinc tetraphenylporphyrin
ZOT	zinc oxide thickener
ZOV	zinc oxide viscosity
ZPD	zinc pentamethylene
ZPG	zero pollution growth
Zr	zirconium
ZS	zinc stannate
ZSK	twin-screw kneader
ZST	zero-strength time
Z-twist	twisting fiber direction
ZXB	zinc butyl zanthate

Appendix B

CONVERSION TABLES

The following data uses the decimal point (that is, a period as used in the United States) rather than a comma (as widely used in the rest of the world).

1. Alphabetical List of Units
2. Temperature Conversions
3. SI Prefixes
4. Units in Use with SI
5. Recommended Pronunciation

1. Alphabetical List of Units

Convert from	To	Multiply by
acre (43,560 square U.S. survey feet)	square meter (m^2)	4046.873
ampere hour	coulomb (C)	3600
angstrom	meter (m)	1.0×10^{-10}
	nanometer (nm)	0.1
are	square meter (m^2)	100
atmosphere, standard	pascal (Pa)	1.01325×10^5
	kilopascal (kPa)	101.325
bar	pascal (Pa)	1.0×10^5
	kilopascal (kPa)	100
barrel (oil, 42 U.S. gallons)	cubic meter (m^3)	0.158988
	liter (L)	158.987
board foot	not clearly defined	
British thermal unit (Btu) (international table)	joule (J)	1055.056
British thermal unit (Btu) (thermochemical)	joule (J)	1054.350
Btu per cubic foot (Btu/ft^3)	joule per cubic meter (J/m^3)	3.7259×10^4
Btu per degree Fahrenheit (Btu/°F)	joule per kelvin (J/K)	1899.101
Btu per hour (Btu/h)	watt (W)	0.2930711
Btu per hour square foot [Btu/(h · ft^2)]	watt per square meter (W/m^2)	3.154591
Btu per pound (Btu/lb)	joule per kilogram (J/kg)	2326
Btu per pound degree Fahrenheit	joule per kilogram kelvin	4186.8
Btu per second (Btu/s)	watt (W)	1055.056
Btu per square foot (Btu/ft^2)	joule per square meter (J/m^2)	1.135653×10^4
bushel (dry, U.S.)	cubic meter (m^3)	0.03523907
calorie (thermochemical)	joule (J)	4.184
calorie (nutrition or kilocalorie)	joule (J)	4184
calorie per gram (cal/g)	joule per kilogram (J/kg)	4184
calorie per second (cal/s)	watt (W)	4.184
candela per square inch (cd/in.^{2})	candela per square meter (cd/m^2)	1550.003
candle, candlepower	candela (cd)	1.0
centimeter of water	pascal (Pa)	98.0665
centipoise	pascal second (Pa · s)	0.001
centistokes	square meter per second (m^2/s)	1.0×10^{-6}
chain (66 U.S. survey feet)	meter (m)	20.11684
circular mil	square millimeter (mm^2)	5.067×10^{-4}
cord	cubic meter (m^3)	3.625
cubic foot (ft^3)	cubic meter (m^3)	0.028317
cubic foot per second (ft^3/s)	cubic meter per second (m^3/s)	0.028317
cubic inch (in.^{3})	cubic meter (m^3)	1.638706×10^{-5}
cubic mile	cubic meter (m^3)	4.168182×10^9
	cubic kilometer (km^3)	4.168182
cubic yard (yd^3)	cubic meter (m^3)	0.764555
cup (U.S.)	cubic meter (m^3)	2.366×10^{-4}
	liter (L)	0.2366
	milliliter (mL)	236.6
curie	becquerel (Bq)	3.7×10^{10}
day (mean solar)	second(s)	8.64×10^4
degree	radian (rad)	0.017453
degree Celsius (°C) (interval)	kelvin (K)	1.0
degree Celsius (°C) (temperature)	kelvin (K)	$t_{°C} + 273.15$
degree Centigrade (interval)	degree Celsius (°C)	1.0

Convert from	To	Multiply by
degree Centigrade (temperature)	degree Celsius (°C)	1, 0
degree Fahrenheit (°F) (interval)	kelvin (K)	0.5555556
	degree Celsius (°C)	0.5555556
degree Fahrenheit (°F) (temperature)	kelvin (K)	$(t_{°F} + 459.67)/1.8$
	degree Celsius (°C)	$(t_{°F} - 32)/1.8$
degree Fahrenheit hour per Btu (°F · h/Btu)	kelvin per watt (K/W)	1.895634
degree Fahrenheit square foot hour per Btu (°F · ft^2 · h/Btu)	Kelvin square meter per watt (K · m^2/W)	0.1761102
degree Fahrenheit square foot hour per Btu inch [°F · ft^2 · h/(Btu · in.)]	kelvin meter per watt (K · m/W)	6.933472
degree Rankine (°R) (interval)	kelvin (K)	0.5555556
degree Rankine (°R) (temperature)	kelvin (K)	$T_{°R}/1.8$
denier	kilogram per meter (kg/m)	1.111×10^{-7}
dyne	newton (N)	1.0×10^{-5}
dyne centimeter	newton meter (N · m)	1.0×10^{-7}
dyne per square centimeter	pascal (Pa)	0.1
electron volt	joule (J)	1.602×10^{-19}
erg	joule (J)	1.0×10^{-7}
erg per second	watt (W)	1.0×10^{-7}
erg per square centimeter	watt per square meter (W/m^2)	0.001
faraday	coulomb (C)	9.649×10^{4}
fathom	meter (m)	1.8288
fermi	meter (m)	1.0×10^{-15}
	femtometer (fm)	1.0
foot	meter (m)	0.3048
foot (U.S. survey)	meter (m)	0.3048006
foot of water	pascal (Pa)	2989.07
	kilopascal (kPa)	2.98907
foot pound-force (ft · lbf) (torque)	newton meter (N · m)	1.355818
foot pound-force (ft · lbf) (energy)	joule (J)	1.355818
foot candle	lux (lx)	10.76391
foot lambert	candela per square meter (cd/m^2)	3.426
g_n (standard acceleration of free fall)	meter per second squared (m/s^2)	9.80665
gallon (Imperial)	cubic meter (m^3)	4.54609×10^{-3}
	liter (L)	4.54609
gallon (U.S.) (231 in.^{3})	cubic meter (m^3)	3.785412×10^{-3}
	liter (L)	3.785412
gallon (U.S.) per day	cubic meter per second (m^3/s)	4.381264×10^{-8}
	liter per second (L/s)	4.381264×10^{-5}
gallon (U.S.) per minute (gpm)	cubic meter per second (m^3/s)	6.309020×10^{-5}
	liter per second (L/s)	0.06309020
gallon (U.S.) per horsepower hour	cubic meter per joule (m^3/J)	1.410089×10^{-9}
gamma	tesla (T)	1.0×10^{-9}
gauss	tesla (T)	1.0×10^{-4}
gill (U.S.)	cubic meter (m^3)	1.183×10^{-4}
grad, grade, gon	radian (rad)	0.01570796
	degree of angle (°)	0.9
grain	kilogram (kg)	6.4799×10^{-5}
hectare	square meter (m^2)	1.0×10^{4}
horsepower (550 ft · lbf/s)	watt (W)	745.6999
horsepower (boiler) (≅33470 Btu/h)	watt (W)	9809.50
horsepower (electric)	watt (W)	746
horsepower (metric)	watt (W)	735.4988
horsepower (water)	watt (W)	746.043
hour	second(s)	3600
hour (sidereal)	second(s)	3590.170
hundredweight, long (112 lb)	kilogram (kg)	50.80235
hundredweight, short (100 lb)	kilogram (kg)	45.35924
inch	meter (m)	0.0254
inch of mercury	pascal (Pa)	3386.39
	kilopascal (Pa)	3.38639
inch of water	pascal (Pa)	249.089
Kelvin (K) (temperature)	degree Celsius (°C)	$T_K - 273.15$
kilocalorie (thermochemical)	joule (J)	4184

Convert from	To	Multiply by
kilogram-force	newton (N)	9.80665
kilogram-force meter	newton meter (N · m)	9.80665
kilogram-force per square centimeter	kilopascal (kPa)	98.0665
kilogram-force per square meter	pascal (Pa)	9.80665
kilometer per hour	meter per second (m/s)	0.278
kilowatt hour	joule (J)	3.6×10^6
	megajoule (MJ)	3.6
kip (1000 lbf)	kilonewton (kN)	4.448222
knot (nautical mile per hour)	meter per second (m/s)	0.5144444
lambert	candela per square meter (cd/m^2)	3183.099
light year	meter (m)	9.46053×10^{15}
liter	cubic meter (m^3)	0.001
lumen per square foot	lumen per square meter (lm/m^2)	10.76391
Maxwell	Weber (Wb)	1.0×10^{-8}
microinch	meter (m)	2.54×10^{-8}
	micrometer (μm)	0.0254
micron	meter (m)	1.0×10^{-6}
	micrometer (μm)	1.0
mil (0.001 in.)	meter (m)	2.54×10^{-5}
	millimeter (mm)	0.0254
mil (angle)	radian (rad)	9.8175×10^{-4}
	degree (°)	0.05625
mile (international) (5280 ft)	meter (m)	1609.344
mile (nautical)	meter (m)	1852
mile (U.S. statute)	meter (m)	1609.347
mile per gallon (U.S.) (mpg)	meter per cubic meter (m/m^3)	4.2514×10^5
	kilometer per liter (km/L)	0.4251437
mile per hour	meter per second (m/s)	0.44704
	kilometer per hour (km/h)	1.609344
mile per minute	meter per second (m/s)	26.8224
millimeter of mercury	pascal (Pa)	133.3224
minute	second(s)	60
minute (arc)	radian (rad)	2.9089×10^{-4}
minute (sidereal)	second(s)	59.836.17
ohm centimeter	ohm meter (Ω · m)	0.01
ounce (avoirdupois)	kilogram (kg)	0.02834952
	gram (g)	28.34952
ounce (Imperial fluid)	cubic meter (m^3)	2.84131×10^{-5}
	milliliter (mL)	28.4131
ounce (troy or apothecary)	kilogram	0.0311348
	gram (g)	31.10348
ounce (U.S. fluid)	cubic meter (m^3)	2.95735×10^{-5}
	milliliter (mL)	29.5735
ounce-force	newton (N)	0.2780139
parsec	meter (m)	3.08568×10^{16}
peck (U.S. dry)	cubic meter (m^3)	8.809768×10^{-3}
	liter (L)	8.809768
pennyweight	kilogram (kg)	1.555174×10^{-3}
	gram (g)	1.555174
perm (0°C)	kilogram/(Pa · s · m^2)	5.72135×10^{-11}
perm inch (0°C)	kilogram/(Pa · s · m)	1.45322×10^{-12}
pica (computer) (1/6 in.)	millimeter (mm)	4.233333
pica (printer's)	millimeter (mm)	4.2175
pint (Imperial)	cubic meter (m^3)	5.6826×10^{-4}
	liter (L)	0.56826
pint (U.S. dry)	cubic meter (m^3)	5.5061×10^{-4}
	liter (L)	0.55061
pint (U.S. liquid)	cubic meter (m^3)	4.73176×10^{-4}
	liter (L)	0.473176
point (computer) (1/72 in.)	millimeter (mm)	0.3527778
point (printer's)	millimeter (mm)	0.35146
poise	pascal second (Pa · s)	0.1
pound (avoirdupois)	kilogram (kg)	0.45359237
pound (troy or apothecary)	kilogram (kg)	0.3732417

Convert from	To	Multiply by
poundal	newton (N)	0.138255
poundal per square foot	pascal (Pa)	1.488164
pound-force	newton (N)	4.448222
pound-force foot (lbf · ft) (torque)	newton meter (N · m)	1.355818
pound-force per foot (lbf/ft)	newton per meter (N/m)	14.59390
pound-force per pound (lbf/lb)	newton per kilogram (N/kg)	9.8066
pound-force per square inch (lbf/in.^{2}) (psi)	pascal (Pa)	6894.757
	kilopascal (kPa)	6.894757
pound per cubic foot (lb/ft^3)	kilogram per cubic meter (kg/m^3)	16.01846
pound per cubic inch (lb/in.^{3})	kilogram per cubic meter (kg/m^3)	2.767990×10^4
pound per cubic yard (lb/yd^3)	kilogram per cubic meter (kg/m^3)	0.5932764
pound per foot (lb/ft)	kilogram per meter (kg/m)	1.488164
pound per gallon (U.S.) (lb/gal)	kilogram per cubic meter (kg/m^3)	119.8264
	kilogram per liter (kg/L)	0.1198264
pound per horsepower hour [lb/(hp · h)]	kilogram per joule (kg/J)	1.689659×10^{-7}
pound per hour (lb/h)	kilogram per second (kg/s)	1.25998×10^{-4}
pound per inch (lb/in.)	kilogram per meter (kg/m)	17.85797
pound per minute (lb/min)	kilogram per second (kg/s)	0.007559873
pound per square foot	kilogram per square meter (kg/m^2)	4.882428
pound per yard	kilogram per meter (kg/m)	0.4960546
quart (U.S. dry)	cubic meter (m^3)	0.001101221
	liter (L)	1.101221
quart (U.S. liquid)	cubic meter (m^3)	9.463529×10^{-4}
	liter (L)	0.9463529
rad (absorbed dose)	gray (Gy)	0.01
ream (printing paper)	sheets	500
rem (dose equivalent)	sievert (Sv)	0.01
revolution	radian (rad)	6.283185
revolution per minute (rpm)	radian per second (rad/s)	0.1047198
rod (16.5 U.S. survey feet)	meter (m)	5.029210
roentgen	coulomb per kilogram (C/kg)	2.58×10^{-4}
second (angle)	radian (rad)	4.8482×10^{-6}
second (sidereal)	second(s)	0.9972696
square inch (in.^{2})	square meter (m^2)	6.4516×10^{-4}
square mile	square meter (m^2)	2.58999×10^6
square yard (yd^2)	square meter (m^2)	0.8361274
stokes	square meter per second (m^2/s)	1.0×10^{-4}
tablespoon	cubic meter (m^3)	1.479×10^{-5}
	milliliter (mL)	14.79
teaspoon	cubic meter (m^3)	4.929×10^{-6}
	milliliter (mL)	4.929
tex	kilogram per meter (kg/m)	1.0×10^{-6}
therm (EEC)	joule (J)	1.0551×10^8
therm (U.S.)	joule (J)	1.0548×10^8
ton, assay	gram (g)	29.16667
ton, long (2240 lb)	kilogram (kg)	1016.047
ton, metric	kilogram (kg)	1000
tonne	kilogram (kg)	1000
ton, register	cubic meter (m^3)	2.831685
ton, short (2000 lb)	kilogram (kg)	907.1847
ton of refrigeration (12,000 Btu/h)	watt (W)	3516.853
ton (long) per cubic yard	kilogram per cubic meter (kg/m^3)	1328.939
ton (short) per cubic yard	kilogram per cubic meter (kg/m^3)	1186.553
torr	pascal (Pa)	133.322
watt	ergs per second	1×10^7
watt hour	joule (J)	3600
watt per square centimeter (W/cm^2)	watt per square meter (W/m^2)	1.0×10^4
watt per square inch (W/in.^{2})	watt per square meter (W/m^2)	1550.003
watt second	joule (J)	1.0
yard	meter (m)	0.9144
year of 365 days	second(s)	3.1536×10^7
year (sidereal)	second(s)	3.1558×10^7
year (tropical)	second(s)	3.1558×10^7

−210 to 0

C.	C. or F.	F.
−134	**−210**	−346
−129	**−200**	−328
−123	**−190**	−310
−118	**−180**	−292
−112	**−170**	−274
−107	**−160**	−256
−101	**−150**	−238
−95.6	**−140**	−220
−90.0	**−130**	−202
−84.4	**−120**	−184
−78.9	**−110**	−166
−73.3	**−100**	−148
−67.8	**−90**	−130
−62.2	**−80**	−112
−56.7	**−70**	−94
−51.1	**−60**	−76
−45.6	**−50**	−58
−40.0	**−40**	−40
−34.4	**−30**	−22
−28.9	**−20**	−4
−23.3	**−10**	14
−17.8	**0**	32

1 to 25

C.	C. or F.	F.
−17.2	**1**	33.8
−16.7	**2**	35.6
−16.1	**3**	37.4
−15.6	**4**	39.2
−15.0	**5**	41.0
−14.4	**6**	42.8
−13.9	**7**	44.6
−13.3	**8**	46.4
−12.8	**9**	48.2
−12.2	**10**	50.0
−11.7	**11**	51.8
−11.1	**12**	53.6
−10.6	**13**	55.4
−10.0	**14**	57.2
−9.44	**15**	59.0
−8.89	**16**	60.8
−8.33	**17**	62.6
−7.78	**18**	64.4
−7.22	**19**	66.2
−6.67	**20**	68.0
−6.11	**21**	69.8
−5.56	**22**	71.6
−5.00	**23**	73.4
−4.44	**24**	75.2
−3.89	**25**	77.0

26 to 50

C.	C. or F.	F.
−3.33	**26**	78.8
−2.78	**27**	80.6
−2.22	**28**	82.4
−1.67	**29**	84.2
−1.11	**30**	86.0
−0.56	**31**	87.8
0	**32**	89.6
0.56	**33**	91.4
1.11	**34**	93.2
1.67	**35**	95.0
2.22	**36**	96.8
2.78	**37**	98.6
3.33	**38**	100.4
3.89	**39**	102.2
4.44	**40**	104.0
5.00	**41**	105.8
5.56	**42**	107.6
6.11	**43**	109.4
6.67	**44**	111.2
7.22	**45**	113.0
7.78	**46**	114.8
8.33	**47**	116.6
8.89	**48**	118.4
9.44	**49**	120.2
10.0	**50**	122.0

51 to 75

C.	C. or F.	F.
10.6	**51**	123.8
11.1	**52**	125.6
11.7	**53**	127.4
12.2	**54**	129.2
12.8	**55**	131.0
13.3	**56**	132.8
13.9	**57**	134.6
14.4	**58**	136.4
15.0	**59**	138.2
15.6	**60**	140.0
16.1	**61**	141.8
16.7	**62**	143.6
17.2	**63**	145.4
17.8	**64**	147.2
18.3	**65**	149.0
18.9	**66**	150.8
19.4	**67**	152.6
20.0	**68**	154.4
20.6	**69**	156.2
21.1	**70**	158.0
21.7	**71**	159.8
22.2	**72**	161.6
22.8	**73**	163.4
23.3	**74**	165.2
23.9	**75**	167.0

76 to 100

C.	C. or F.	F.
24.4	**76**	168.8
25.0	**77**	170.6
25.6	**78**	172.4
26.1	**79**	174.2
26.7	**80**	176.0
27.2	**81**	177.8
27.8	**82**	179.6
28.3	**83**	181.4
28.9	**84**	183.2
29.4	**85**	185.0
30.0	**86**	186.8
30.6	**87**	188.6
31.1	**88**	190.4
31.7	**89**	192.2
32.2	**90**	194.0
32.8	**91**	195.8
33.3	**92**	197.6
33.9	**93**	199.4
34.4	**94**	201.2
35.0	**95**	203.0
35.6	**96**	204.8
36.1	**97**	206.6
36.7	**98**	208.4
37.2	**99**	210.2
37.8	**100**	212.0

101 to 340

C.	C. or F.	F.
43	**110**	230
49	**120**	248
54	**130**	266
60	**140**	284
66	**150**	302
71	**160**	320
77	**170**	338
82	**180**	356
88	**190**	374
93	**200**	392
99	**210**	410
100	**212**	413
104	**220**	428
110	**230**	446
116	**240**	464
121	**250**	482
127	**260**	500
132	**270**	518
138	**280**	536
143	**290**	554
149	**300**	572
154	**310**	590
160	**320**	608
166	**330**	626
171	**340**	644

341 to 490

C.	C. or F.	F.
177	**350**	662
182	**360**	680
188	**370**	698
193	**380**	716
199	**390**	734
204	**400**	752
210	**410**	770
216	**420**	788
221	**430**	806
227	**440**	824
232	**450**	842
238	**460**	860
243	**470**	878
249	**480**	896
254	**490**	914

491 to 750

C.	C. or F.	F.
260	**500**	932
266	**510**	950
271	**520**	968
277	**530**	986
282	**540**	1004
288	**550**	1022
293	**560**	1040
299	**570**	1058
304	**580**	1076
310	**590**	1094
316	**600**	1112
321	**610**	1130
327	**620**	1148
332	**630**	1166
338	**640**	1184
343	**650**	1202
349	**660**	1220
354	**670**	1238
360	**680**	1256
366	**690**	1274
371	**700**	1292
377	**710**	1310
382	**720**	1328
388	**730**	1346
393	**740**	1364
399	**750**	1382

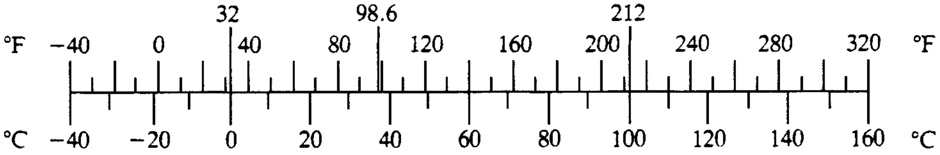
NOTE:—The numbers in bold face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right.

$$°F = \frac{9}{5}(°C) + 32$$

$$°C = \frac{5}{9}(°F - 32)$$

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	1	1.8	3.33	6	10.8
1.11	2	3.6	3.89	7	12.6
1.67	3	5.4	4.44	8	14.4
2.22	4	7.2	5.00	9	16.2
2.78	5	9.0	5.56	10	18.0



3. SI Prefixes

Multiplication Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deka	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	η
0.000 000 000 001 = 10^{-12}	pico	ρ
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

4. Units in Use with SI

Quantity	Unit	Symbol	Definition
Time	Minute	min	1 min = 60 s
	Hour	h	1 h = 60 min = 3600 s
	Day	d	1 d = 24 h = 86400 s
	Week, month, etc.	. . .	. . .
Plane angle	Degree	°	$1° = (\pi/180)$ rad
	Minute	′	$1' = (1/60)°$ $= (\pi/10800)$ rad
	Second	″	$1'' = (1/60)'$ $= (\pi/648000)$ rad
Volume	Litre	L	1 L = 1 dm^3 = 10^{-3} m^3
Mass	Metric ton	t	1 t = $10^{3\ kg}$
Area	Hectare	ha	1 ha = 1 hm^2 = 10^4 m^2

5. Recommended Pronunciation

Prefix	Pronunciation (U.S.)	Selected Units	Pronunciation
exa	ex' a (*a* as in *a*bout)	candela	can*dell'* a
peta	pet' a (*e* as in pet, *a* as in *a*bout)	joule	rhyme with *tool*
tera	as in *terra* firma	kilometer	*kill'* oh meter
giga	jig' a (*i* as in jig, *a* as in *a*bout)	pascal	rhyme with *rascal*
mega	as in *mega*phone	siemens	same as *seamen's*
kilo	kill' oh		
hecto	heck' toe		
deka	deck' a (*a* as in *a*bout)		
deci	as in *deci*mal		
centi	as in *centi*pede		
milli	as in *mili*tary		
micro	as in *micro*phone		
nano	nan' oh (*an* as in *ant*)		
pico	peek' oh		
femto	fem' toe (*fem* as in *fem*inine)		
atto	as in an*atom*y		

Note: The first syllable of every prefix is accented to assure that the prefix will retain its identity. Pronunciation of kilometer places the accent on the first syllable, *not* the second.

Appendix C

WORLDWIDE PLASTICS INDUSTRY ASSOCIATIONS

The following list, organized alphabetically by country, includes an example of the global list of the plastics industry and other relevant associations. Groups covering all of Europe or all of South America are listed under Pan European and Pan-South American groups.

AFRICA

African Plastics Industry
tel: 27(0) 21 671-9889
web: http://mbendi.co.za/indy/chem/plasaf.htm

Republic of South Africa
Plastics Federation of South Africa
18 Gazelle Ave., Corporate Park
Old Pretoria Rd., Midrand
Private Bag X68, Halfway House, 1685
tel:+27 (11) 314 4021
fax:+27 (11) 314 3764

ALGERIA

National Enterprise of Plastics and Rubber
BP 452-453 Zone Industrielle
Setif 19000
tel: (213) 590-8157
fax: (213) 590-0665

ARGENTINA

Argentine Chamber of the Plastics Industry (CAIP)
J. Salguero 1939/41, Buenos Aires 1425
tel: (5411) 4821-9603/5
fax: (5411) 4826-5480
web: http://www.caip.org.ar

Plastivida Argentina
Av. Leandro N. Alem 1067 piso 14 of. 54
10001 Beunos Aires, Argentina
tel: (54) 4311-1136
e-mail: mensajes@plastivida.com.ar
web: http://www.plastivida.com.ar

AUSTRALIA

Composites Institute of Australia Inc. (CIA)
PO Box 672, Ringwood Victoria 3134
tel: +61 (39) 723-5688
fax: +61 (39) 723-5786
web: http://www.compinst.asn.au/index.html

Medical Industry Association of Australia
PO Box 497, Roseville
New South Wales 2069
tel: +61 29 4151 1151
fax: +61 29 4152 130
e-mail: miaa@ozemail.com.au

Plastics and Allied Industries Association of South Australia (PAIA)
e-mail: plassatf@plasticsa.org.au
web: http://www.plasticsa.org.au

Plastics and Chemicals Industries Association (PACIA)
380 St. Kilda Rd., 4th floor, P.O. Box 1610M
Melbourne, Victoria 3001
tel: +61 (3) 9699 6299
fax: +61 (3) 9699 6717
e-mail: info@pacia.org.au
web: http://www.pacia.org.au/

AUSTRIA

Federation of Chemical Industry Austria Plastics Processors
Wiedner Hauptstrasse 63
A-1045 Vienna
tel: +43 (1) 501 053 340
fax: +43 (1) 502 062 80

Kunststoffhersteller-Verband (KV)
Jakobergasse 4/14
A-1010 Vienna
e-mail: kv@telekabel.at

National Guild of Plastics Processors
Wiedner Haupstrasse 63
A-1045 Vienna
tel: +43 (1) 501 05 3234
fax: +43 (1) 502 06 291
e-mail: fcio@wkoesk.wk.or.at
web: http://www.wk.or.at/fcio

BELGIUM

Association of Belgian Plastics Converters
Fabrimetal Group 18 (Fabriplast)
Diamant Building
Bd. A. Reyers LN
B-1030 Brussels, Belgium
tel: +32 (2) 706-7800

fax: +32 (2) 706-7801
e-mail: gustaaf.bos@fabrimetal.be
web: http://www.fabrimetal.be

European Committee for Electrotechnical Standardization (CENELEC)
Rue de Stassart 35
Brussels B-1050
tel: +32 (2) 5196871
fax: +32 (2) 5196919
e-mail: general@cenelec.be
web: http://www.cenelec.be

European Committee for Standardization (CEN)
Rue de Stassart 36
Brussels B-1050
fax: +32 (2) 5500819
web: http://www.cenorm.be

Federation of Belgian Chemical Industries (FEDICHEM)
Square Marie-Louise 49
B-1000 Brussels
tel: +32 (2) 238-9711
e-mail: postmaster@fedichem.be
web: http://www.vbo-feb.be/chemistry

BOLIVIA

Aniplast c/o Plasmar
Casilla 942
La Paz
fax: +591 (2) 850 581

BRAZIL

Brazilian Plastics Industry Association (Abiplast)
Avenida Paulista 2439, 8th floor
São Paulo SP 01311-936 Brazil
tel: +55 (11) 3060 9688
fax: +55 (11) 3060 9686
e-mail: abiplast@abiplast.org.br
web: http://www.celit.senai.br/cadastro%20assocc/ABIPLAST.htm

Brazil Plastics on the Internet
web: http://plastics.com.br/en_index.htm

Brazilian Polymer Association
Associacão Brasileira de Polímeros (Abpol)
Rua Geminiano Costa, 355
São Paulo SP 013560-050
tel/fax: +55 (16) 274-3949
web: http://www.abpol.com.br

Instituto do PVC
Rua James Watt. 142-conj.122 andar-conj. 42
São Paulo SP-CEP 04576-050
tel/fax: +55 (11) 5506 5211
web: http://www.institutodopvc.org/english

Plastivida Brazil
e-mail:spra@abiquim.org.br
web: http://www.abiquim.org.br/plastivida/english

CANADA

Alliance of Manufacturers and Exporters Canada
5595 Avebury Road, Suite 900
Mississauga, Ontario L5R 3P9
tel: (905) 568-8300
fax: (905) 568-8330
e-mail: webmaster@the-alliance.com
web: http://www.the-alliance.org

Association of Consulting Engineers of Canada
130 Albert St., Suite 616
Ottawa, Ontario K1P 5G4
tel: (613) 236-0569
fax: (613) 236-6193
e-mail: memserv@acec.ca
web: http://www.acec.ca

Automotive Parts Manufacturers' Association
195 West Mall, Suite 516
Toronto, Ontario M9C 5K1
tel: (416) 620-4220
fax: (416) 620-9730
e-mail: apma@capma.com
web: http://www.capma.com

Canadian Association of Chemical Distributors
627 Lyons Lane, Suite 301
Oakville, Ontario L6J 5Z7
tel: (905) 844-9140
fax: (905) 844-5706
e-mail: cacd@cacd.ca
web: http://cacd.ca/cacdmain.html

Canadian Association for Composite Structures and Materials
c/o NRC 75 Boulevard de Mortagne
Boucherville, Quebec J4B 6Y4
tel: (450) 641-5149
fax: (450) 641-5105
web: http://www.cacsma.ca

Canadian Association of Moldmakers
424 Tecumseh Road East
Windsor, Ontario N8A 2R6
tel: (519) 255-7863
web: http://www.cdnmolds.com

Canadian Chemical Producers' Association (CCPA)
350 Sparks St., Suite 805
Ottawa, Ontario K1R 7S8
tel: (613) 237-6215
fax: (613) 237-4061
e-mail: info@ccpa.ca
web: http://www.ccpa.ca

Canadian Plastics Industry Association (CPIA)
5925 Airport Rd., Suite 500

Mississauga, Ontario L4V 1W1
tel: (905) 678-7748
fax: (905) 678-0774
e-mail: national@cpia.ca
web: http://www.plastics.ca

Canadian Polystyrene Recycling Association (CPRA)
7595 Tranmere Dr.
Mississauga, Ontario L5S 1L4
tel: (905) 612-8290
fax: (905) 612-8024
web: http://www.cpra-canada.com

Canadian Standards Council of Canada
45 O'Connor Street, Suite 1200
Ottawa, Ontario K1P 6N7
tel: (613) 238-3222
fax: (613) 995-4564
web: http://www.scc.ca

Chemical Institute of Canada
130 Slater St., Suite 550
Ottawa, Ontario K1P 6E2
tel: (613) 232-6252
fax: (613) 232-5862
e-mail: cic_adm@fox.nstn.ca
web: http://www.chem-inst-can.org

Environment and Plastics Industry Council (EPIC) (See Canadian Plastics Industry Association)
e-mail: shill@cpia.ca
web: http://www.plastics.ca

Medical Devices Canada (MEDEC)
401 The West Wall, Suite 510
Etobicoke, ON M9C 5J5
tel: (416) 620-1915
fax: (416) 620-1595
e-mail: medec@medec.org
web: http://www.medec.org

Packaging Association of Canada
2255 Sheppard Ave East, Suite 330
Willowdale, Ontario M2J 4Y1
tel: (416) 490-7860
fax: (416) 490-7844
web: http://www.pac.ca

Sign Association of Canada
7030 Woodbine Ave., Suite 500
Markham, Ontario L3R 6G2
tel: (905) 470-9787
fax: (905) 470-8993

Underwriters' Laboratories of Canada
7 Crouse Rd.
Scarborough, Ontario L5B 2V2
tel: (416) 757-3611
fax: (416) 757-9540
e-mail: ulcinfo@ulc.ca
web: http://www.ulc.ca

CHILE

Chilean Plastics Industry Association (Asipla)
Av. Andrés Bello 2777, 5°Piso Oficina 507
Las Condes, Santiago
tel: +56 (2) 203-3342
fax: +56 (2) 203-3343
web: http://www.asipla.cl

CHINA

China Plastics Processing Industry Association (CPPIA)
Rm 114, N°6 East ChangAn Ave.
100740, Beijing, China
tel: +86 (10) 651-22056
fax: +86 (10) 652-25254
e-mail: ccpia@ihw.com.cn

Federation of Hong Kong Industries
Hankow Centre, 4th floor
5-15 Hankow Rd., Tsim Sha Tsui,
Kowloon, Hong Kong
tel: +852 (2) 732 3188
fax: +852 (2) 721 3494
e-mail: fhk@fhki.org.hk
web: http://www.fhki.org.hk

Hong Kong Plastics Manufacturers' Association Ltd.
1/F, Flat B, Fo Yuen, 39-49 Wanchai Rd.
Wanchai, Hong Kong
tel: +852 574 2230
fax: +852 574 2843

Hong Kong Plastics Technology Centre Co. Ltd.
U 509 Hong Kong Polytechnic University
Hung Hom Kowloon, Hong Kong
tel: +852 2 766 5577
fax: +852 2 766 0131
web: http://www.plastics-ctr.org.hk

COLOMBIA

Colombian Plastics Industry Association (Acoplasticos)
Calle 69 No. 5-33
Aptdo. Aereo 29844
Santa Fe Bogotá, Colombia
tel: +57 (1) 346-0655
fax: +57 (1) 249 6997
e-mail: acoplast@cable.net.co
web: http://www.sitio.de/acoplasticos

COSTA RICA

Costa Rican Association of the Plastics Industry
Apartado 8247
1000 San Jose
tel/fax: (506) 55 0961

CYPRUS

Cyprus Plastics Processors Association
P.O. Box 1455
Nicosia 1509
tel: +357 (2) 669 500
fax: +357 (2) 665 685

CZECH REPUBLIC

Confederation of Plastics Industry of the Czech Republic
Mikulandská 7
CZ-113 61 Praha (Prague) 1
tel: +42 (2) 2491 5678
fax: +42 (2) 297 896

Czech Packaging Association
Jecná 11
CZ-120 00 Praha (Prague) 2
tel/fax: +42 (2) 292 370

DENMARK

Danish Plastics Federation (PLASTINDUSTRIEN)
48 Norre Voldgade
Copenhagen K DK-1358
tel: +45 (331) 330 22
fax: +45 (391) 108 98
e-mail: pd@plast.dk
web: http://www.plastindustrien.dk

ECUADOR

Ecuadorian Plastics Association (Aseplas)
ESPOL-Campus Prosperina
Facultad de Ingenieria Mecanica
Edif 18B, Guayaquil
tel: +593 (4) 269 383
fax: +593 (4) 269 383
e-mail: aseplas@espol.edu.ec
web: http://www.espol.edu.ec/aseplas

FINLAND

Finnish Plastics Industries Federation
Eteläranta 10, 7th floor, PL 4
Helsinki 00130
tel: 358 (9) 17 28 41
fax: 358 (9) 63 02 25
web: http://www.chemind.fi

FRANCE

National Syndicate of Rubber, Plastics and Associated Industries
web: http://www.proplast.org

Professional Syndicate of Plastic Materials Producers (SPMP); Syndicat des Producteurs de Matières Plastiques (SPMP)
14, rue de La Republique
Puteaux 92800 France
tel: +33 (01) 46 53 1053
fax: +33 (01) 46 53 1073
web: http://www.spmp.proplast.org

GERMANY

Association for Engineering Plastics
Am Hauptbahnhof 10
Frankfurt/Main D-60329
tel: +49 (69) 250 920
fax: +49 (69) 250 919

Association of the Plastics Processing Industry (GKV)
Am Hauptbahnhof 12
D-60329 Frankfurt am Main
tel: +49 (69) 271 0520
fax: +49 (69) 232 799
e-mail: info@gkv.de
web: http://www.gkv.de

German Association of Plastics Manufacturers Verband Kunststofferzeugende (VKE)
Karlstrasse. 21
Frankfurt D-60329
tel: +49 (69) 255 613 03
fax: +49 (69) 251 060
e-mail: http://info@vke.de
web: http://www.vke.de

Institute for Design Theory and Plastic Machinery (KKM)
Schützenbalm 70
D-45127 Essen
tel: +49 (201) 183-3975
fax: +49 (201) 183-2877

Institute for Plastics Processing (IKV)
Pontstrasse 49
D-52062 Aachen
tel: +49 (241) 8038 66
fax: +49 (241) 8888-262

Plastics Packaging Association (IK)
Kaiser-Friedrich-Promenade 43
D-61348 Bad Homburg v.d.H.
tel: +49 6172 926 667
fax: +49 6172 926 669
web: http://www.kunststoffverpackungen.de

Rubber and Plastics Machinery Division (VDMA)
Lyoner Str. 18
Frankfurt 60528
tel: +49 (69) 660 31832
fax: +49 (69) 660 31840
e-mail: guk@vdma.org
web: http://www.guk.vdma.org

Society of Independent Plastics Engineers and Consultants
Am Hauptbahnhof 12
Frankfurt/Main D-60329
tel: +49 (69) 271 050
fax: +49 (69) 232 799

GREECE

Association Hellenic Plastics Industries
60 Michalakopoulu
GR-611 Athens
tel: +30 (1) 77 94 519
fax: +30 (1) 77 94 518
e-mail: aegis@ath.fothnet.gr

HUNGARY

Association of the Hungarian Plastics Industry
Magyar Münyagipari Szövetség, POB. 4
H-1406 Budapest 76
tel/fax: +36 (1) 343-0759
e-mail: mmsz-mcssz@mail.matav.hu

INDIA

All India Plastics Manufacturers' Association
A.52, Street No. 1 M.I.D.C., Marol, Andheri (E)
Bombay 400 093
tel: +91 (22) 821-7324
fax: +91 (22) 821-6390
e-mail: info@aipma.org
web:http://www.aipma.org

Indian Plastics Institute
5BM Polytechnic (Plastics Dept)
Irla Vileparle (West)
Bombay 400 056
Maharashtra, India
tel: +91 (22) 616-1775
fax: +91 (22) 610-5770
e-mail: ipi@bom3.vsnl.net.in
web: http://www.inplasin.org

Organization of Plastics Processors of India
Moderna House, Ground floor
88-C, Old Prabhadevi Rd.
Bombay 400 053 India
tel: +91 (22) 634 6975
e-mail: oppi@bom5.vsnl.net.in
web: http://www.oppindia.org

Plastindia Foundation
2, Leela Apts., 355 S.V. Rd.
Vile Parle (West), Bombay 400 056
tel: +91 (22) 671-2500
fax: +91 (22) 671-1906
e-mail: info@plastindia.org
web: http://www.plastindia.org

INDONESIA

Federasi Industri Plastik Indonesia (Fiiplasin)
c/o PT Mada Wikri Tunggal
Jalan Letjen, Tebet Dalam IV No. 67
Jakarta 12820
tel/fax: +62 (21) 829-9790

IRAQ

Iraqi Federation of Industries
Khulani Square, PO Box 5665
Baghdad
tel: 964 (1) 888 009
fax: 964 (1) 888 2305

IRELAND

Plastics Industries Association
Irish Business and Employers Confederation
Confederation House
84-86 Lower Baggot St.
Dublin 2
tel: +353 (1) 660-1011
fax: +353 (1) 660-1717
web: http://www.ibec.ie

ISRAEL

Institute for Advancement of Packaging and Design
2, Carlebach St.
Tel Aviv 61200
tel: +972 (3) 561-4404
fax: +972 (3) 561-1451
e-mail: packdeg@netvision.net.il

Society of Israel Plastics and Rubber Industry
c/o Manufacturers Association of Israel
29 Harnered St.
PO Box 50022
Tel Aviv 61500
tel: +972 (3) 519-8832
fax: +972 (3) 510-3154
e-mail: gendiv@industry.org.il
web:http://www.industry.org.il

ITALY

Assogomma
Via S. Vittore 36
Milan 20123
tel: +39 (2) 466 020
fax: +39 2) 435 432

Federchimica Assoplast
Via Accademia 33
I-20131 Milano
tel: +39 (2) 268 101

fax: +39 (2) 268 10311
e-mail: info@plastica.it
web: http://www.plastica.it

Italian Plastics and Rubber Processing Machinery and Mold Manufacturers' Association (Assocomplast)
PO Box 24, Assago (MI) 20090
tel: +39 (2) 822 8371
fax: +39 (2) 575 1249
e-mail: assocomaplast@assocomaplast.com
web:http://www.assocomaplast.com

National Union of the Plastics Processing Industry (UnionPlast)
Via Petitti 16
I-20149 Milano
tel: 39 (2) 392-10425
fax: 39 (2) 392-66548

JAPAN

Association of Japan Plastics Machinery Manufacturers
2-10-18 Ginza Chuo-ku
Tokyo 104
tel./fax: +81 (3) 3542-8575

Japan Expanded Polystyrene Recycling Association (JEPSRA)
6F Shouwaakihabara Bldg.
2-20 Sakuma-cho, Kanda
Chiyoda-ku Tokyo 101-0025
tel: +81 (3) 38 61 9046
fax: +81 (3) 38 61 0096
e-mail: jepsra@infotera.or.jp
web: http://www.jepsra.gr.jp

Japan PET Bottle Association
Nihonbashi Mi Bldg., 2nd Floor
1-4-3 Nihonbashi-Horidome
Chiyoda-ku Tokyo
Japan 103-0021
tel: +81 (3) 36 62 7591
fax: +81 (3) 56 23 2885
web: http://www.petbottle-rec.gr.jp

Japan Plastics Industry Federation
5-18-17 Roppongi
Minato-ku, Tokyo 106
tel: +81 (3) 3586 9761
fax: +81 (3) 3586 9760

Plastic Waste Management Institute (PWMI)
Fukide Bldg., 1-13, 4 Chome
Toranomon, Minato-ku
Tokyo 105
tel: +81 (3) 3437 225
fax: +81 (3) 3437 5270
web: http://www.pwmi.or.jp

KOREA

Korea Plastic Industry Cooperative
146-2 Ssangnim-dong, Chung-gu
Seoul 100-400, Korea
tel: +82 (2) 275-7991
fax: +82 (2) 279-6857

Korea Plastics Industry Cooperative
e-mail: info@koreaplastic.or.kr
web: http://www.koreaplastic.or.kr

Korea Reclaimed Plastic Industry Corp.
94-121 Youngdungpo-dong,
Youngdungpo-gu Seoul 150-020 Korea
tel: +82 (2) 677-0331
fax: +82 (2) 671-6136

LEBANON

General Syndicate of Plastics Materials Processors
PO Box 11
6635 Beirut
tel: +961 (1) 86 06 9
fax: +961 (1) 2124 781 532

MALAYSIA

Malaysian Plastic Manufacturers Association (MPMA)
37 Jalan 20/14, Paramount Garden
46300 Petaling Jaya
Selangor
tel: +60 (3) 776-3027
fax: +60 (3) 776-8352
web: http://mpma.org.my

Malaysian Rubber Products Manufacturers' Association
1A Jalan USJ 11/1J
47620 Subang Jaya, Malaysia
tel: 60 (3) 731-6150
fax: 60 (3) 731-6152
web: http://www.mrpma.com

MEXICO

American Chamber of Commerce
Lucerna 78, Colonia Juarez
Del. Cuauhtemoc
06600 Mexico, D.F.
tel: +52 (5) 724-3800
fax: +52 (5) 703-3908
e-mail: amchammex@amcham.com.mx
web: http://www.amcham.com.mx

Asociación Nacional de Envase y Embalaje A.C.
(Mexican Association of Bottling and Packaging)
Homero 538-70 1/2

Colonia Chapultepec Morales
11570 Mexico D.F.
tel: +52 (5) 531-9856
fax: +52 (5) 546-2023
web: http://www.cosmos.com.mx/env/4dwl.htm

Asociación Nacional de Importadores y Exportadores de la República Mexicana (ANIERM)
(National Association of Importers and Exporters of Mexico)
Monterrey 130, 1st floor
Colonia Roma
06700 Mexico, D.F.
tel: +52 (5) 584-9522
fax: +52 (5) 584-5317
e-mail anierm@anierm.org.mx
web: http://www.anierm.org.mx

Asociación Nacional de la Industria del Plástico A.C. (Anipac)
(National Association of the Plastics Industry)
Av. Parque Chapultepec 66
Despacho-301, 3er Piso, Col. El Parque
CP 53390 Naucalpan de Juarez
tel: +52 (5) 576-5547
fax: +52 (5) 576-5548
e-mail: anipac@inetcorp.net.mx
web: http://www.inetcorp.net.mx/anipac

Asociación Nacional de la Industria Quimica A.C. (ANIQ)
(National Chemistry Industry Association)
Providencia 1118
Colonia del Valle C.P.
03100 Mexico, D.F.
tel: +52 (5) 230-5100
fax: +52 (5) 230-5107
e-mail: alorea@aniq.org.mx
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e-mail: info@mappinc.com
web: http://www.mappinc.com

NACE International
PO Box 218340
Houston, TX 77218-8340
tel: (281) 228-6200
fax: (281) 228-6300
e-mail: msd@mail.nace.org
web: http://www.nace.org

National Association for Plastic Container Recovery (NAPCOR)
2105 Water Ridge Parkway #570
Charlotte, NC 28217
tel: (704) 423-9400
fax: (704) 423-9500
email: jwindischmann@napcor.com
web: http://www.napcor.com

National Association of Home Builders
1201 15th St. N.W.
Washington, DC 20005
tel: (202) 822-0520
fax: (202) 822-0374
e-mail: lewood@compuserve.com
web: http://www.nahb.com

National Association of Manufacturers (NAM)
1331 Pennsylvania Ave. NW, Suite 600
Washington, DC 20004-1790
tel: (202) 637-3000
fax: (202) 637-3182
e-mail: manufacturing@nam.org
web: http://www.nam.org

National Association of Plastics Fabricators
1100 Standard Bldg.
Cleveland, OH 44113

National Association of the Remodeling Industry
4900 Seminary Rd., Suite 320
Alexandria, VA 22311
tel: (703) 575-1100
fax: (703) 575-1121
e-mail: info@nari.org
web: http://www.nari.org

National Beverage Packaging Association/Food Processing Machinery and Supplies Association
200 Daingerfield Rd.

Alexandria, VA 22314-2800
tel: (703) 684-1080
fax: (703) 548-6563
e-mail: info@fpmsa.org
web: http://www.fpmsa.org

National Electrical Manufacturers Association (NEMA)
1300 North 17th St., Suite 1847
Rosslyn, VA 22209
tel: (703) 841-3200
fax: (703) 841-3300
e-mail: webmaster@nema.org
web: http://www.nema.org

National Fenestration Rating Council
c/o D&R International
1300 Spring St., Suite 500
Silver Spring, MD 20910
tel: (301) 589-6372
fax: (301) 588-0854
web: http://www.nfrc.org

National Fire Protection Association
PO Box 9101
1 Batterymarch Park
Quincy, MA 02269-9101
tel: (617) 770-3000
fax: (617) 770-0700
e-mail: library@nfpa.org
web: http://www.nfpa.org

National Housewares Manufacturers Association (NHMA)
6400 Shafer Court, Suite 650
Rosemont, IL 60018
tel: (847) 292-4200
fax: (847) 292-4211
e-mail: info@nhma.com
web: http://www.housewares.org

National Institute of Building Sciences (NIBS)
1090 Vermont Ave. NW, Suite 700
Washington, DC 20005-4905
tel: (202) 289-7800
fax: (202) 289-1092
e-mail: nibs@nibs.org
web: http://www.nibs.org

National Paint and Coatings Association
1500 Rhode Island Ave., N.W.
Washington, DC 20005
tel: (202) 462-6272
fax: (202) 462-8549
e-mail: npca@paint.org
web: http://www.paint.org

National Plastics Center and Museum
210 Lancaster Street, Route 117
PO Box 639
Leominster, MA 01453
tel: (978) 537-9529
fax: (978) 537-3220
e-mail: vwilcox@polymers.com
web: http://www.polymers.com/npcm/

National Recycling Coalition
1727 King St., Suite 105
Alexandria, VA 22314-2070
tel: (703) 683-9025
fax: (703) 683-9026
web: http://www.nrc-recycling.org

National Soft Drink Association (NSDA)
1101 16th St. NW
Washington, DC 20036-4877
tel: (202) 463-6732
fax: (202) 463-8277
e-mail: mcavanagh@nsda.com
web: http://www.nsda.org

National Solid Wastes Management Association (NSWMA)
4301 Connecticut Ave. NW, Suite 300
Washington, DC 20008
tel: (202) 244-4700
fax: (202) 966-4841
e-mail: info@envasns.org
web: http: www.envasns.org

National Tooling and Machining Association
9300 Livingston Rd.
Fort Washington, MD 20744-4998
tel: (301) 248-6200
fax: (301) 248-7104
web: http://www.ntma.org

North American Insulation Manufacturers Association
44 Canal Center Plaza, Suite 310
Alexandria, VA 22314
tel: (703) 684-0084
fax: (703) 684-0427
e-mail: insulation@naima.org
web: http://www.naima.org

NSF International
PO Box 130140
Ann Arbor, MI 48113-0140
tel: (734) 769-8010
fax: (734) 769-0109
e-mail: info@nsf.org
web: http://www.nsf.org

Packaging Machinery Manufacturers Institute (PMMI)
4350 North Fairfax Dr., Suite 600
Arlington, VA 20003
tel: (703) 243-8555
fax: (703) 243-8556
e-mail: pmmi@pmmi.org
web: http://www.packexpo.com

Plastic Bag Federation/SPI
355 Lexington Ave., 17th floor
New York, NY 10017
tel (212) 661-4261
fax: (212) 370-9047
e-mail: pbainfo@aol.com
web: http://www.plasticbag.com

Plastic Loose-Fill Council
P.O. Box 21040
Oakland, CA 94620
tel: (800) 828-2214
fax: (510) 654-0196
web: http://www.loosefillpackaging.com

Plastic Lumber Trade Association
PO Box 80311
Akron, OH 44308-9998
tel: (330) 762-1963
fax: (330) 762-1963

Plastic Pipe and Fittings Association
800 Roosevelt Rd.
Building C, Suite 20
Glen Ellyn, IL 60137
tel: (630) 858-6540
fax: (630) 790-3095

Plastics and Composites Group
P.O. Box 248
Piscataway, NJ 08855-0248
tel: (732) 672-1131
fax: (732) 445-0777

Plastic Shipping Container Institute
1920 North St NW
Washington, DC 20036
tel: (202) 973-2709
fax: (202) 331-8330

Plastics Institute of America Inc. (PIA)
Plastics Institute of America
@University of Massachusetts-Lowell
333 Aiken St.
Lowell, MA 01854
tel: (978) 934-3130
fax: (978) 459-9420
e-mail: pia@cae.uml.edu
web: http://www.eng.uml.edu/~pia

Plastics Molders & Manufacturer's Assoc. (PMMA) of SME
1 SME Dr., PO Box 930
Dearborn, MI 48121-0930
tel: (313) 271-1500
fax: (313) 271-2861
e-mail: skomche@sme.org
web: http://www.sme.org/pmma

Plastics Pioneers Association
19 Freedom Court
Greer, SC 29650
tel: (864) 879-7279
fax: (864) 879-7309

Plastics Processors Association of Ohio
4040 Embassy Parkway, Suite 180
Akron, OH 44333
tel: (330) 665-4891
fax: (330) 665-5152
e-mail: kkeiper@ppaohio.org
web: http://www.ppaohio.org

Polyisocyanurate Insulation Manufacturers Association (PIMA)
1331 F Street, NW, Suite 975
Washington, DC 20004
tel: (202) 628-6558
fax: (202) 628-3856
e-mail: pima@pima.org
web: http://www.pima.org

Polymer Processing Institute
Suite 3901, Guttenburg Information Technologies Center
New Jersey Institute of Technology
University Heights
Newark, NJ 07102-1982
tel: (973) 596-5896
fax: (973) 642-4594
e-mail: info@polymers-ppi.org
web: http://www.polymers-ppi.org

Polyurethane Foam Association
PO Box 1459
Wayne, NJ 07474-1459
tel: (973) 633-9044
fax: (973) 628-8986
web: http://www.pfa.org

Polyurethane Manufacturers Association (PMA)
800 Roosevelt Rd.
Building C, Suite 20
Glen Ellyn, IL 60137-5833
tel: (630) 858-2670
fax: (630) 790-3095
e-mail: info@pmahome.org
web: http://www.pmahome.org

Regulatory Affairs Professionals Society (RAPS)
12300 Twinbrook Pkwy., Suite 350
Rockville, MD 20852
tel: (301) 770-2920
fax: (301) 770-2924
e-mail: raps@raps.org
web: http://www.raps.org/start.html

Retail Packaging Manufacturers' Association (RPMA)
PO Box 17656
Covington, KY 41017-0656
tel: (606) 341-9623
fax: (606) 341-9624

Polyolefins Fire Performance Council
179 Peaceable St.
Ridgefield, CT 06877
tel: (203) 438-1754
fax: (203) 431-4375

Southern Regional Office
Nationsbank Bldg., Suite 606
7 N Laurens St.
Greenville, SC 29601
tel: (864) 239-2939
fax: (864) 239-0549
e-mail: rsturgis@socplas.org
web: http://www.spisouth.org

Western Regional Office
215 Michelan Dr., Suite 24c
Irving, CA 92612
tel: (949) 261-6979
fax: (949) 261-6959
e-mail: cap.clmp@souplas.org
web: http://www.spiwest.org

Solid Waste Association of North America (SWANA)
1100 Wayne Ave., Suite 700
Silver Spring, MD 20910
tel: (301) 585-2898/(800) 467-9262
fax: (301) 589-7068
web: http://www.swana.org

Structural Insulated Panel Association (SIPA)
3413A 56th St. N.W.
Big Harbor, WA 98335
tel: (253) 858-7472
fax: (253) 858-0272
e-mail: staff@sips.org
web: http://www.sips.org

Suppliers of Advanced Composite Materials Association (SACMA)
1600 Wilson Blvd., Suite 901
Arlington, VA 22209
tel: (703) 841-1556
fax: (703) 841-1559
e-mail: wwerst@sacma.org
web: http://sacma.org

Synthetic Organic Chemical Manufacturers Association
1850 M St., NW, Suite 700
Washington, DC 20036
tel: (202) 721-4100
web: http://www.socma.org

Ultrasonic Industry Association (UIA)
1250 Arthur E. Adams Dr.
Columbus, OH 43221
tel: (614) 688-5111
fax: (614) 688-5001
e-mail: uia@ultrasonics.org
web: http://www.ultrasonics.org

Underwriters Laboratories (UL)
333 Pfingsten Rd.
Northbrook, IL 60062
tel: (847) 272-8800
fax: (847) 272-8129
web: http://www.ul.com

U.S. ASEAN Council
1400 L St. NW, Suite 375
Washington, DC 20005
tel: (202) 289-1911
fax: (202) 289-0519

URUGUAY

Uruguayan Association of Plastics Industries
Av. General Rondeau 1665
11100 Montevideo
tel: +598 (2) 923 405
fax: +598 (2) 922 567

VENEZUELA

Venezuelan Plastics industry Association (Avipla)
Edifo. Multicentro Macaracuay, 7th floor
Ave. Principal de Macaracuay
Carasas
tel: 58 (2) 256-3345
fax: 58 (2) 256 2867
web: http://www.avipla.com

Venezuelan Bureau of Small and Medium Plastic, Rubber and Related Industries
Ave. Principal de la Cooperativa,
Qta. Maria Elisa, Detras de Malariologia
Maracay 2101, Estado Araguay
tel: .58 43-41 542
fax: .58 43-41 70 63

VIETNAM

Vietnam Plastics Manufacturers Association (VPMA)
92-94 Ly tu Trong St., District 1
Ho Chi Minh City
tel: 84 (8) 822 9022
fax: 84 (8) 822 9266
e-mail: vpma@vol.vnn.vn

YUGOSLAVIA

Plastic Industry Business Association (Juplas)
Sv. Save 1—Hotel "Slavija"
YU-11000 Belgrade
tel/fax: 381 11 444 6144

Appendix D

WORLDWIDE PLASTICS INDUSTRY EVENTS

January

Injection Molding Management Conference Sponsored by *Injection Molding Magazine*. Contact (303) 321-2322 or fax (303) 321-3552.

Automotive News World Congress Sponsored by Automotive News. Contact (313) 446-1620 or fax (313) 446-8030.

International Builders Show Sponsored by the National Association of Home Builders. Contact (202) 861-0520 or fax (202) 822-0374.

International Composites Expo (ICE) Sponsored by the SPI Composites Institute. Contact (212) 351-5404 or fax (212) 370-1731.

International Housewares Show Sponsored by the National Housewares Manufacturers Association. Contact (847) 292-4200 or fax (847) 292-4211.

Medical Design and Manufacturing West Conference and Exhibition and Pacific Design Engineering Show Sponsored by Canon Communications LLC. Contact (310) 996-9421 or fax (310) 996-9429.

Minnesota Plastics Industry Day Organized by the SPI Midwest Regional Office. Contact (773) 380-0808 or fax (773) 380-0008.

North American International Auto Show Sponsored by the Detroit Auto Dealers Association. Contact (248) 643-0250 or fax (248) 643-8788.

Nova-Pack Americas (International conference on rigid polyester packaging innovations for food and beverages) Sponsored by Schotland Business Research Inc. Contact (609) 466-9191, fax (609) 466-8833, or e-mail robin@schotland.com.

Western Plastics Expo Sponsored by Advanstar Expositions. Contact (216) 891-2637, fax (216) 862-2801, or e-mail motionexpo@advanstar-expos.com.

February

Society of Automotive Engineer International Congress and Exposition Sponsored by the Society of Automotive Engineers. Contact (412) 772-7131, fax (412) 776-0002, or e-mail meetings@sae.org.

Society of the Plastics Industry Molders and Moldmakers Annual Conference Contact (202) 974-5247 or fax (202) 974-7005.

March

American Chemical Society National Meeting Contact (202) 872-4396 or fax (202) 872-6128.

Applied Plastics Technology and Design Conference Sponsored by the SPI Structural Plastics Division. Contact (202) 974-5200 or fax (202) 296-7005.

ASEANplas Contact Düsseldorf Trade Shows at (212) 356-0400 or fax (212) 356-0404.

Association of Rotational Molders Spring Meeting Contact (630) 571-0611 or fax (630) 571-0616.

Corrosion Sponsored by Nace International. Contact (281) 228-6223 or fax (281) 492-8254.

Fire Retardant Chemicals Association Meeting Contact (717) 291-5616 or fax (717) 295-4538.

Flexible Packaging Association Annual Meeting Contact (202) 842-3880 or fax (202) 842-3841.

GLOBEC'98 (chemical, petrochemical, and plastics industry production and products) Sponsored by Maack Business Services. Contact +41 (1) 781 30 40 or fax +41 (1) 781 15 69.

Midwest Recycling Investment Forum Organized by KirkWorks and the Nebraska Department of Economic Development. Contact KirkWorks at (919) 220-8065, fax (919) 220-9720 or e-mail david@kirkworks.com.

Molding: Emerging Technologies in Injection Molding Sponsored by Executive Conference Management. Contact (313) 420-0507 or fax (313) 420-2280.

National Design Engineering Show and Conference Organized by Reed Exhibition Co. Contact (203) 840-5856 or fax (203) 840-9856.

NEPCON West Sponsored by Reed Exhibition Co. Contact (203) 840-5358, fax (203) 840-9856, or e-mail inquiry@nepcon.reedexpo.com.

North American Material Handling Show and Forum Sponsored by the Material Handling Industry of America. Contact (704) 676-1190 or fax (704) 676-1199.

Pakex Sponsored by Reed Exhibition Cos. Contact (203) 840-5393 or fax (203) 840-9570.

Polyurethane Manufacturers Association Spring Meeting Contact (630) 858-2670 or fax (630) 790-3095.

SAE International Conference & Exposition Sponsored by the Society of Manufacturing Engineers. Contact (724) 772-7131 or fax (724) 776-0006.

Society of the Plastics Industry Plastic Drum Institute Spring Conference Contact (202) 974-5243 or fax (202) 296-7005.

Society of the Plastics Industry Structural Plastics Contact (202) 974-5309 or fax (202) 974-7005.

Society of the Plastics Industry Thermoforming Institute Winter Meeting Contact SPI West at (714) 261-6979, fax (714) 261-6959, or e-mail westreg@socplas.org.

Society of the Plastics Industry Vinyl Siding Institute Members Only Spring Meeting Contact (202) 974-6326 or fax (202) 974-7005.

Southeast Recycling Conference and Trade Show Contact (334) 277-7050 or fax (334) 277-7080.

April

Argenplás Organized by the Argentine Chamber of the Plastics Industry. Contact +54 (1) 374-1320, fax +54 (1) 826-5480 or e-mail banpaku@ibm.net.

Automotive News Southeast Conference Contact Tommie Himes at the University of Tennessee at (615) 327-2487 or fax (615) 327-0118.

Packaging Strategies Sponsored by Packaging Strategies. Contact (610) 436-4220, fax (610) 436-6277 or e-mail meetings@packstrat.com.

The Plastics Show Sponsored by Traverse Lerew Group Inc./ISOA International Inc. Contact (440) 878-1282, fax (440) 878, 1284, or e-mail information @plashow.com.

PU China Organized by Industrial Promotions International and Crain Communications. Contact Jennifer Poda at (330) 865-6109 or fax (330) 836-1005.

Society of Plastics Engineers Annual Technical Conference (ANTEC) Contact (203) 775-0471 or fax (203) 775-8490.

Society of the Plastics Industry Foamed Polystyrene Alliance Annual Conference Contact (202) 974-5227 or fax (202) 296-7005.

Society of the Plastics Industry Machinery and Moldmakers Division Spring Conference Contact (202) 974-5231 or fax (202) 296-7005.

Society of the Plastics Industry Midwest: Ohio Plastics Summit Contact (773) 380-0808 or fax (773) 380-0008.

World Petrochemical Review Organized by Dewitt & Co. Contact (281) 774-7200 or fax (281) 774-7210.

May

Automotive and Transportation Interiors Expo Produced by Shore-Varrone Inc. Contact (404) 252-8831 or fax (404) 252-4436.

Chinaplas Sponsored by Euromap. Contact +49 (69) 6603-1831 or fax +49 (69) 6603-1840.

International Society for the Advancement of Material and Process Engineering Symposium and Exhibition (SAMPE) Contact (800) 562-7360, ext. 610, fax (626) 332-8929 or e-mail sampeibo@aol.com.

Plast-Ex Sponsored by the Canadian Plastics Industry Association. Contact (416) 323-1883 or fax (416) 323-9404.

Society of Manufacturing Engineers Rapid Prototyping and Manufacturing Conference and Exposition Contact (313) 271-1500, ext. 629, or fax (313) 271-2861.

Society of the Plastics Industry Sheet Producers Division Meeting Contact (202) 974-5234 or fax (202) 296-7005.

Society of the Plastics Industry Vinyl Institute Annual Meeting Contact (201) 898-6699 or fax (201) 898-6633.

Society of the Plastics Industry Western Section Conference Contact (714) 261-6979 or fax (714) 261-6959.

June

Color Pigments Manufacturers Association Inc. Annual Meeting Contact (703) 684-4044 or fax (703) 684-1795.

ELECTRO/NEPCON East (electronics design, production, and packaging) Sponsored by Reed Exhibition Cos. and the Electronics Industries Forum of New England. Contact Reed at (203) 840-5358, fax (203) 840-9856, or e-mail inquiry@nepcon.reedexpo.com.

Engineering Thermoplastics Sponsored by *Modern Plastics* and Maack Business Services. Contact Maack at +41 (1) 781-3040 or fax +41 (1) 781-1569.

Flexpo sponsored by Chemical Market Resources Inc. Contact (281) 333-3313, fax (281) 333-3361.

Latinpack Sponsored by Acoplasticos. Contact LatinPack Inc. at tel./fax (847) 577-2435 or e-mail latinpack98@latinmail.com.

MetCon Polymers in Transition Organized by the Catalyst Group. Contact (215) 628-4447 or fax (215) 628-2267.

NPE, National Plastics Exposition Chicago. Held every three years. Contact SPI (202) 974-5200.

Plastics Fair-Cleveland Sponsored by Advanstar Expositions. Contact (216) 891-2637, fax (216) 826-2801, or e-mail motionexpo@advanstar-expos.com.

Replitech North America Sponsored by Knowledge Industry Publications. Contact (800) 800-5474 or fax (914) 328-2020.

Society of the Plastics Industry Midwest Conference Contact (773) 380-0808 or fax (773) 380-0008.

TechMed (manufacturing processes in medical technology) Organized by P.E. Schall GmbH. Contact +49 (70) 25-9206 0, fax +49 (70) 25-9206 20, or e-mail techmed@schall-messen.de.

July

Plastics Asia Organized by Business and Industrial Trade Fairs Ltd. Contact +852 2865 2633 or fax +852 2866 1770.

August

Auto Tech Sponsored by the Automotive Industry Action Group. Contact (248) 358-3570 or fax (248) 358-3253.

CADCOMP (computer-aided design in composite material technology) Organized by Wessex Institute of Technology. Contact +44 (1703) 29 32 23, fax +44 (1703) 29 28 53, or e-mail wit@wessex.ac.uk.

Compounding Sponsored by Executive Conference Management Inc. Contact (313) 420-0507 or fax (313) 420-2280.

University of Michigan Management Briefing Sponsored by the University of Michigan Office for the Study of Automotive Transportation. Contact (313) 647-9096 or fax (313) 764-5592.

September

Autofact Conference and Exposition Contact the Society of Manufacturing Engineers at (313) 271-1500 or fax (313) 271-2861.

CMM Europe (converting machinery and materials) Organized by Miller Freeman Group USA. Contact (212) 615-2200 or fax (212) 643-5604.

Labelexpo USA Organized by Labelex USA Inc. Contact Stephen Krogulski at (847) 318-1500, fax (847) 318-1506, or e-mail labelexusa@labelresource.com.

Packaging and Food Processing Indonesia Organized by members of the Montgomery Network. Contact Francois Gros, IMEX Management Inc. at (704) 365-0041 or fax (704) 365-8426.

Pacprocess Drink-technology ASEAN. Organized by Düsseldorf Trade Fair Co. and Munich Trade Fair Co. Contact (212) 356-0400 or fax (212) 356-0404.

Plastimagen Mexico City. Contact CPREX at +52 (5) 785-7553, fax +52 (5) 785-7638, or e-mail inform @cprex.com.mx.

Plastics Fair–Atlantic City Sponsored by Advanstar Expositions. Contact (216) 891-2637, fax (216) 826-2801, or e-mail motionexpo@advanstar-expos.com.

Society of Plastics Engineers Thermoforming Division Conference and Exhibition Sponsored by the Society of Plastics Engineers. Contact SPE (203) 775-0471.

Society of the Plastics Industry Polyurethane Expo Contact (212) 351-5425 or fax (212) 697-0409.

Wisconsin Plastics and Manufacturing Expo Organized by Expo Productions Inc. Contact (414) 367-5500 or fax (414) 367-9956.

October

Association of Rotational Molders Fall Meeting Contact (630) 571-0611 or fax (630) 571-0616.

Automotive Recyclers Association Convention and Exposition Contact (703) 385-1001 or fax (703) 385-1494.

Fire Retardant Chemicals Association meeting Contact (717) 291-5616 or fax (717) 295-4538.

International Bottled Water Association Convention and Trade Show Contact (703) 683-5213.

Kunstsoffe Sponsored by Düsseldorf Trade Shows. Contact (212) 356-0400 or fax (212) 356-0404.

Plastics USA Sponsored by SPI. Contact (202) 974-5235, fax (202) 296-7243 or e-mail tradeshows@ socplas.org.

Polypropylene Sponsored by Maack Business Services. Contact +41 (1) 781 30 40 or fax +41 (1) 781 15 69.

Polyurethane Foam Association Meeting Contact SPE (202) 974-5200.

Polyurethane Manufacturers Association Fall Meeting Contact (630) 858-2670 or fax (630) 790-3095.

Society of the Plastics Industry Epoxy Resin Formulators Division Meeting Contact (202) 974-5234 or fax (202) 296-7005.

TPOs in Automotive Sponsored by Executive Conference Management. Contact (313) 420-0507 or fax (313) 420-2280.

November

Pack Expo Sponsored by the Packaging Machinery Manufacturers Institute. Contact (703) 243-8555, fax (703) 243-8556, or e-mail bkilduff@pmmi.noli.com.

The Plastics Show Sponsored by Traverse Lerew Group Inc./ISOA International Inc. Contact (440) 878-1282, fax (440) 878-1284 or e-mail information @plashow.com.

Society of the Plastics Industry Southern Conference Contact (864) 213-2414 or fax (864) 288-7937.

Wilson Forum—East, (column wrapping) Organized by Wilson Composlte Group Inc. Contact (916) 989-4812, fax (916) 989-1714 or e-mail norma_anders/wcgi/ us@wcgi.com.

December

Total Life Cycle Conference and Exposition Contact SAE International at (412) 772-7131, fax (412) 776-1830, or e-mail gadzia@sae.org.

Appendix E

U.S. GOVERNMENT PUBLICATIONS AND GROUPS

Bureau of the Census (www.census.gov)
Annual Survey of Manufacturers
Census of Manufacturers
Foreign Trade Reports
Guide for Foreign Trade Statistics

Bureau of Labor Statistics (BLS) (www.bls.gov)
Producer Price Indexes
Wholesale Price Index

Department of Commerce (www.doc.gov)
Office of Microelectronics, Medical Equipment, and Instrumentation (OMMI), International Trade Administration (ITA)
Statistical Abstracts of the United States
U.S. Government Publications (5285 Port Royal Rd., Springfield, VA 22161)
U.S. Industrial Outlook

Environmental Protection Agency (EPA) (www.epa.gov)

Export-Import Bank of the United States (www.exim.gov)

Federal Trade Commission (FTC) (www.ftc.gov)

Federal Web Locator (provides links to federal agencies) (www.infoctr.edu/fwll)

Food and Drug Administration (FDA) (www.fda.gov)
Division of Small Manufacturers Assistance, Center for Devices and Radiological Health (1350 Piccard Dr., HFZ 220, Rockville, MD 20850, tel 800-638-2041)

Health Care Financing Administration (HCFA) (www.hcfa.gov)

Library of Congress (LOC) (101 Independence Ave. SE, Washington, DC 20540, tel 202-707-5000) (www.loc.gov)

National Institute of Standards and Technology (NIST) (Polymer Bldg., Room A-903, Gaithersburg, MD 20899, tel 301-975-NIST, fax 301-926-1630) (www.nist.gov)
Directory of Plastics: Knowledgeable Government Personnel

Naval Publications and Forms Center (5801 Tabor Rd., Philadelphia, PA 19120) (www.asrl.com/refe.htm)

Nuclear Regulatory Commission (NRC) (www.nrc.gov)

Occupational Safety and Health Administration (OSHA) (www.osha.gov)
Occupational Safety and Health Review Commission

Office of Management and Budget (OMB) (www.whitehouse.gov/omB)
Standard Industrial Classification Manual
Statistical Services of the U.S. Government

Plastics Technical Evaluation Center (PLASTEC) (Picatinny Arsenal, Dover, NJ 07801) (www.pica.army.mil)

Small Business Administration (SBA) (www.sba.gov)

Appendix F

TRADE MAGAZINES AND PUBLICATIONS

The industry has worldwide trade magazines and publications that provide useful information to industry personnel. The following listing provides examples of what is available.

Advanced Materials and Processes
ASM International
9639 Kinsman Rd.
Materials Park, OH 44073-0002
tel: (440) 338-5151/(800) 336-5152

British Plastics and Rubber
MCM Publishing Ltd.
37 Nelson Road
Caterham, Surrey CR3 5PP, UK
tel: +44 (0) 1883 37059

Canadian Plastics
1450 Don Mills Rd.
Don Mills, Ont.
Canada M3B 2X7
tel: (416) 445-6641

Chemical and Engineering News
733 Third Ave.
New York, NY 10017
tel: (212) 872-4600

Chemical Engineering
Two Penn Plaza, 5th Flr.
New York, NY 10121-2298
tel: (212) 904-2000

Chemical Market Reporter
Schnell Publishing Co., Inc.
Two Recter Street
New York, NY 10006
tel: (212) 791-4267

Chemical Week
888 Seventh Ave., 26th floor
New York, NY 10106
tel: (212) 621-4900

Composites Fabrication Magazine
1855 N Fort Myer Drive, Suite 510
Arlington, VA 22209
tel: (703) 525-0511

Design News
275 Washington St.
Newton, MA 02158
tel: (617) 558-4660

European Chemical News
Quadrant House, The Quadrant
Sutton, Surrey, SM2 5AS, UK
tel: +44 (0) 181 652 3153

European Plastics News
Emap Maclaren Ltd.
233 High Street
Croydon, CR0 9XT UK
tel: +44 (0) 181 277 5000
Other publications:
Asian Plastics News
Plastics and Rubber Weekly
Materials Recycling Week

European Polymer Journal
Elsevier Science
P.O. Box 211, 1000 AE Amsterdam
The Netherlands
tel: +31-20-4853757
(212) 633-3730 (U.S./NYC)
Other publications:
Additives for Polymers
Journal of Materials Processing Technology
Reinforced Plastics

Injection Molding Magazine
59 Madison Ave., Suite 770
Denver, CO 80206
tel: (303) 321-2322

Inside Line/Electronics OEM, The
333 Washington Ave. N., Suite 343
Minneapolis, MN 55401
tel: (612) 373-7080

International Polymer Science and Technology
RAPRA Technology Ltd.
Shawbury, Shrewsbury
Shropshire SY4 4NR UK
tel: +44 (0) 1939 250 383
Other publications:
Focus on Plastics Additives
Plastics News Japan
Progress in Rubber and Plastics Technology

Journal of Commerce
Two World Trade Center, 27th Flr.
New York, NY 10048
tel: (212) 837-7177

Kunststoffe
Carl Hanser Verlag
Kolbergerstrasse 22
D-81679 Munich, Germany
tel: 089-99830 621
Other publications:
International Polymer Processing
PE Plast Europe

Machine Design
Penton Media Inc.
1100 Superior Ave.
Cleveland, OH 44114
tel: (216) 696-7000

Mechanics of Time-Dependent Materials
Kluwer Academic Publishers
101 Philip Drive, Assinippi Park

Norwell, MA 02061
tel: (781) 871-6600
Other publications:
Journal of Materials Science
Applied Composite Materials
Advanced Performance & Materials

Medical Device and Diagnostic Industry
11444 W. Olympic Blvd., Suite 900
Los Angeles, CA 90064
tel: (310) 445-4200

Modern Plastics and Modern Plastics International
Two Penn Plaza
New York, NY 10121
tel: (212) 904-6942

Molding Systems
Society of Manufacturing Engineers (SME)
One SME Drive, PO Box 930
Dearborn, MI 48121
tel: (313) 271-1500/(800) 733-4763
Other publications:
Plastic Parts Production & Design

Moldmaking Technology
650B East Butler Ave.
New Britain, PA 18901
tel: (215) 230-9556

Motion Control Magazine
67 Alexander Dr.
Research Triangle Park, NC 27709
tel: (919) 549-8411

Packaging Digest
1350 E. Touhy Ave.
Des Plaines, IL 60017
tel: (847) 390-2293

Packaging World Magazine
Summit Publishing Company
One IBM Plaza, Suite 2401
330 N. Wabash Avenue
Chicago, IL 60611
tel: (312) 222-1010

Paper, Film and Foil Converter
Intertech Publishing Corp.
P.O. Box 12978
Overland Park, KS 66282-2978
tel: (312) 609-4286

Plastics and Rubber Asia
SRC Communications Group Ltd.
tel: +44 1892 839200
Other publication:
Injection Moulding Asia

Plastics Auxiliaries
P.O. Box 261
Waterford, CT 06385
tel: (860) 443-4119

Plastics Distributor and Fabricator
2701 North Pulaski Road
Chicago, IL 60639
tel: (773) 235-3800

Plastics Engineering
The Society of Plastics Engineers
14 Fairfield Dr.
Brookfield Center, CT 06804-0403
tel: (203) 775-0471

Plastics Focus
Box 814
Amherst, MA 01004
tel: (413) 549-5020

Plastics Information Europe
Kunststoff Information Verlagsgesellschaft
Saalburg Str. 157
Bad Homburg, Germany 61350
tel: 06 172 32007

Plastics News
Crain Communications, Inc.
1725 Merriman Rd., Suite 300
Akron, OH 44313-5283
tel: (330) 836-9180
Other publications:
Rubber and Plastics News
Waste News
European Rubber Journal
Urethanes Technology

Plastics Technology
355 Park Avenue South
New York, NY 10010-1789
tel: (212) 592-6570

Plastics Week
Market Search, Inc.
2727 Holland Sylvania Rd., Suite A
Toledo, OH 43615
tel: (419) 535-7899
Other publications:
Plastics Brief Series
—Injection Molding
—Extrusion
—Blow Molding
Thermoplastic Markets
Design & Materials
Reinforced Plastics
Automotive Plastic News

PT Auxiliaries
355 Park Ave. South,
New York, NY 10010
tel: (212) 592-6580

Rubber World Magazine
Lippincott & Peto Publications
1867 W. Market Street
Akron, OH 44313-6901
tel: (330) 864-2122

SAMPE Journal
SAMPE International Editorial Office
459 N. Gilbert Road, Suite A-150
Gilbert, AZ 85234
tel: (602) 587-6882

World Plastics and Rubber Technology
KIngs Court
2-16 Goodge Street
London W1P 1FF England
tel: +44 171 240 1515

Appendix G

WEBSITES ON PLASTICS

The following sources of information available via websites cover aspects of plastics ranging from products design, material and process equipment selection, product qualification with cost analysis, industry consumption data, and management recruiting.

Advanced Liquid Crystalline Optical Materials (ALCOM) Liquid crystal investigators, research, and conferences. http://alcom.kent.edu/ALCOM/ALCOM.html

Advanced Materials and Processes Technology Information Analysis Center (AMPTIAC) Materials and processing products (books and databooks), technical inquiries, consulting, upcoming conferences, and library services (document location, bibliographies, and referrals). http://rome.iitri.com/amptiac

African Plastics Industry Offering plastics industry profiles of several African nations, plus information on trade associations and links to data on Africa's chemical and other industries. http://mbendi.co.za/indy/chem/plasaf.htm

Alliance of Foam Packaging Recyclers A network for the collection, reprocessing, and reuse of foam packaging. http://www.epspackaging.org

Alfred University Center for Advanced Ceramic Technology (CACT) http://nycc.alfred.edu/external/cact/

Aluminum Consultants Group Provides assistance in materials selection, evaluation/analysis, and development of aluminum alloys. http://www.acgroupinc.com

American Chemical Society (ACS) The site of the world's largest scientific society, with a membership of more than 150,000 chemists and chemical engineers. http://www.acs.org

American Foundrymen's Society (AFS) Society overview, metalcasting-related news, metalcasting-related books and publications, metalcasting training videos. http://www.afsinc.org

American Institute of Chemical Engineers (AIChE) Searches of AICheE-related journals and publications. http://www.aiche.org

American Iron and Steel Institute-Steel Works News, steel links, statistics, markets, and applications and publications. http://www.steel.org/publications

American Mold Builders' Association (AMBA) The 400-member AMBA, founded in 1973, provides this online business center to assist companies that primarily design and build molds. http://www.amba.org

American National Standards Institute (ANSI) Provides access to information on the ANSI federation and latest national and international standards-related activities, with links to related sites. http://www.ansi.org

American Plastics Council (APC) This trade association site details the role of plastics in society, some key end-market applications, and other educational and environmental information. http://www.plastics.org

American Society for Testing and Materials (ASTM) From the work of 132 technical standards-writing committees, ASTM has developed and published more than 10,000 specs, tests, practices, guides, and definitions that are used by industries worldwide. http://www.astm.org

American Society of Materials (ASM) International Major diversified U.S. society for materials engineers. http://www.asm-intl.org

Ames Laboratory, U.S. Department of Energy Noted research facility operated by Iowa State University http://www.external.ameslab.gov

Applied Research Laboratory at Penn State http://www.arl.psu.edu/siteindex/site_index.html

Army Research Laboratory (ARL) http://www.arl.mil/

Asian Plastics Research Association (APRA) The Canberra, Australia-based APRA promotes and disseminates research relating to polymer processing and engineering, market information, and technology. http://users.netinfo.com.au/sira/aprahome.htm

Association of Home Appliance Manufacturers Serves the consuming public and the appliance industry's manufacturers, suppliers, and related professionals. http://www.aham.org

Association of Plastics Manufacturers in Europe (APME) The voice for Europe's polymer-producing industry. Its 40-plus member companies come from 13 European countries and represent more than 90 percent of the continent's polymer output. http://www.apme.org

Association of Rotational Molders (ARM) With more than 400 members, ARM champions the rotomolding industry worldwide. http://www.rotomolding.org

Assocomaplast The nonprofit Assocomaplast, founded in 1960, is a 175-member association representing Italy's plastics, rubber, machinery and molds manufacturers. (in English and Italian) http://www.assocomaplast.com

Battenfeld Gloucester Engineering Co. World-renowned manufacturer of extruded film lines. http://www.battenfeld.com

Bayer Plastics Provides important news releases with material database, processing techniques, and designing marketable products. http://www.plastics.bayer.com/english/home.html

Brazil Plastics on the Internet Brazilian plastics industry's electronic marketplace, supported by INP, Brazil's National Plastics Institute. (in English, Portuguese and Spanish) http://www.plastico.com.br

British Plastics and Rubber Provides on-line updated gateway to plastics sites on the Internet with a directory to around 1,350 UK companies supplying machinery and materials for processors. http://www.polymer-age.co.uk/start.htm

British Plastics Federation (BPF) The London-based BPF was founded more than 60 years ago and has more than 400 members. http://www.bpf.co.uk

California Film Extruders and Converters Association (CFECA) Provides a professional, ethical, and united organization working to improve the polyethylene film industry's business environment. http://www.cfeca.org

Cambridge Scientific Abstracts Bibliographic database covering the world's literature on metals and materials. http://www.csa.com

Canadian Plastics Industry Association (CPIA) Canada's umbrella plastics organization, encompassing the Society of Plastics Industry of Canada, the Canadian Plastics Institute, the Environment and Plastics Institute of Canada and a number of regional bodies. (in English and French) http://www.plastics.ca

Canadian Plastics Magazine Provides news, services, directory, buyers guide, etc. concerning the Canadian plastics industry. http://www.canplastics.com/frmain.htm

Canada Underwriters' Laboratories Canadian safety certification, testing, quality registration, and standards development organization dedicated to the protection of life and property. http://www.ulc.ca/index.htm

Carderock Division, Naval Surface Warfare Center http://www.dt.navy.mil

Carnegie Mellon University, Center for Iron and Steel Research Steel-related links. http://neon.mems.cmu.edu/cisr/cisr.html

Case Western Reserve University, Polymers and Liquid Crystals Background, applications, and preparation plus links to other liquid crystal sites. http://plc.cwru.edu

CenBASE/Materials Searchable database of over 35,000 plastics, metals, composites, and ceramics. http://www.centor.com/cbmat/index.html

Center for Nondestructive Evaluation at Iowa State University http://www.cnde.iastate.edu/cnde.html

ChemExpo Provides search, news, information on trade associations, bookstore, people connections, etc. http://www.chemexpo.com

Chemical Institute of Canada Umbrella organization for the Canadian Society for Chemistry, the Canadian Society for Chemical Engineering, and the Canadian Society for Chemical Technology. http://www.chem-inst-can.org/

Chemical Manufacturers' Association (CMA) Sponsors Responsible Care: the industry's commitment to the public to continuously improve its health, safety, and environmental performance. http://www.cmahq.com

Chemical Week http://www.chemweek.com/index.html

Chlorine Chemistry Council (CCC) Strives to achieve policies that promote the continuing, responsible uses of chlorine and chlorine-based products. http://www.c3.org

Clarkson University-Center for Advanced Materials Processing (CAMP) http://people.clarkson.edu/~dcamp

Clean Washington Center (CWC) Established by the Washington State Legislature in 1991 as the primary state organization to develop markets for recycled materials. http://www.cwc.org

Commercial Development and Marketing Association (CDMA) The CDMA is the world's largest professional association dedicated to fostering, promoting, and sharing business for long-term growth in the chemical and allied industries. http://www.cdmaonline.org

Community of Science, U.S. Patent citation database http://patents.cos.com

Composites Fabricators Association (CFA) Provides composites education worldwide. http://www.cfa-hq.org

Composite Materials Handbook International, up-to-date, statistics-based characterization of current and emerging composite technology and engineering development providing design and fabricating methodologies. http://mil-17.udel.edu/

Composite Registry http://www.compositesreg.com

Construction Resin Home Page (epoxy related) http://homepages.together.net/~norm

Container Recycling Institute (CRI) A nonprofit research and public education organization that studies container and packaging recycling and reuse. The group also serves as a clearinghouse for information on beverage container deposit systems or bottle bills. http://cri.earthsystems.org

Cornell Injection Molding Program http://xenoy.mae.cornell.edu

Corrosion, Protective Coatings, and Paints Resources on the Internet http://www.execpc.com/~rustoleu/coatings.htm

CRT Laboratories, Inc. Certification, testing, standards http://www.crtlabs.com

CS ChemFinder Chemical Information Server-Cambridge Soft http://www.chemfinder.com

Davis-Standard Corp. World leader in the manufacture of all types of precision extrusion machinery. http://www.davis-standard.com

Department of Energy Information Bridge Provides access to DOE research and development reports. http://www.doe.gov/bridge/

Defense Technical Information Center (DTIC) Home Page http://www.dtic.mil/

Document Center Inc. Distributor of specifications and standards documents. http://www.document-center.com

Dow Plastics Dow materials selection guide includes ISO and ASTM database modules for engineering plastics, styrenics, elastomers, and polyolefins. http://www.dow.com/plastics

Drexel University-Fibrous Materials Research Center (FMRC) http://www.materials.drexel.edu/FMRL/fmrc.html

Edinburgh Engineering Virtual Library, UK Engineering information service that provides thousands of websites that includes journals, catalogues, newsgroups, material databases, and directories. http://eevl.icbl.hw.ac.uk/

Edison Welding Institute WeldNet http://www.ewi.org

Electronic Selected Current Aerospace Notices (E-SCAN) http://gopher.sti.nasa.gov/scan/scan.html

Endura Plastics Inc. Provides information for designers, engineers, and others interested in plastics. http://www.endura.com

Environmental Science Center Database http://esc.syrres.com/interkow/database.htm

Epoxy Systems, Inc. Provides extensive information and data on types of epoxies such as material constructions, processing, database, joining, flooring, problems and solutions, etc. http://www.epoxysystems.com

European Chemical Industry Council (CEFIC) Brussels group that comprises national chemical industry federations in 22 European countries plus many chemicals companies. http://www.cefic.org

European Commission-Information Service http://europa.eu.int/geninfo/icom-en.htm

European Committee of Machinery Manufacturers for the Plastics and Rubber Industries (Euromap) This nonprofit group is the European committee of the national associations of plastics and rubber machinery manufacturers, representing some 600 companies. http://www.euromap.org

European Council for Plasticizers and Intermediates The website of this 28-member Brussels body, part of the much larger European Chemical Industry Council (CEFIC), offers information on the health and environmental aspects of plasticizers and intermediate chemicals. http://www.ecpi.org

European Council of Vinyl Manufacturers (ECVM) A division of the Association of Plastics Manufacturers in Europe that represents the interests of Europe's PVC-producing companies. http://www.ecvm.org

European Federation of Chemical Trade (FECC) European national associations of Chemical distribution and trade. http://www.fecc.org

European Isocyanate Producers' Association (ISOPA) e-mail: belsopal@lbmmall

European Organization for Packaging and Environment (Europen) http://www.europen.be

European Plastics Converters (EuPO) This Brussels-based confederation consists of various national plastics processors associations in Europe, with links to those already online. http://www.eupc.org

European Plastics Converters Plastics Recycling Market This multilingual site, operated by the EuPC trade association in Brussels, describes itself as "the global marketplace for the recycling of all plastics." http://www.recytrade.com

Federal Acquisition Jump Station Links to federal government acquisitions on the Internet. http://nais.nasa.gov/fedproc/home.html

Film and Bag Federation The Film and Bag Federation, formerly the Plastic Bag Association, is a consortium of 60 of the industry's leading manufacturers and suppliers, who work together on issues of interest and concern to the industry. http://www.plasticbag.com

Flexible Packaging Association (FPA) Since 1950, the FPA has served as the voice of the flexible packaging industry. Flexible packaging is manufactured from paper, plastic film, aluminum foil, or any combination of these materials, to produce bags, pouches, labels, liners, and wraps for a broad array of products including: food, pharmaceuticals, medical supplies, household goods, pet food, and garden supplies. http://www.flexpack.org

Foodservice and Packaging Institute (FPI) FPI's mission is to promote the sanitary, safety, functional, economic, and environmental benefits of foodservice disposables. http://www.fpi.org

Geofoam WWW Site This site is dedicated exclusively to all aspects of geofoam geosynthetic technology providing timely dissemination and sharing of current information. http://www.geofoam.org

GE Plastics A wealth of data on their materials and services that include data sheets, material selection, processing, literature online, and in-depth technical data. http://www.ge.com/plastics

German Association of Plastics Manufacturers (VKE) This Frankfurt-based trade group, Verband Kunststofferzeugende Industrie e.V., represents Germany's plastic materials producers. (in German and English) http://www.vke.de

German Plastics and Rubber Machinery Association (VDMA) The Frankfurt-based nonprofit organization offers information on members and products, plus facts, related links, and news about Germany's machinery industry. (in German and English) http://www.guk.vdma.org

Global Recycling Network (GRN) A recycling industry business center on the Internet. http://www.grn.com

Green Seal An independent, nonprofit organization dedicated to protecting the environment by promoting the manufacture and sale of environmentally preferable consumer products. http://www.greenseal.org

Grocery Manufacturers of America The Grocery Manufacturers of America is an organization led by the CEOs of Fortune 500 companies that make and market the world's best-known brands of food and consumer packaged goods. http://www.gmabrands.com

Harrel Inc. World-renowned leader of temperature, pressure, etc. instrumentation for primary and secondary processing equipment. http://www.harrel.com

HPM Corp. Major source in the manufacture of injection molding machines. http://www.hpmcorp.com

IBM Intellectual property network. Particularly useful to the novice or occasional searcher. http://www.patents.ibm.com

IDES Worldwide source for plastic materials information, including processing and design software tools They estimate that over 30,000 plastic materials are available in the United States and about 50,000 worldwide with nearly 500 worldwide producers. http://www.idesinc.com. Their Prospector web database (ASTM and ISO) of about 35,000 materials can very quickly find candidate plastics for a given application. http://www.freemds.com

Illinois Institute of Technology, Mechanical, Materials, Aerospace Engineers. http://mmae.iit.edu

Industrial Designers' Society of America (IDSA) This group of more than 2,800 members is dedicated to communicating the value of industrial design to society, business, and government. Its site includes links to several other design-oriented sites. http://www.idsa.org

Industrial Designers Society of America, Materials and Processes Section The Materials and Processes Section of the IDSA has its own website, offering discussion and networking opportunities for design and manufacturing industry professionals. http://www.idsa-mp.org

Injection Molding Magazine Provides up-to-date information in the field of injection molding. http://www.immnet.com

Institute of Packaging Professionals (IOPP) http://www.iopp.org

Integrated Waste Services Association (IWSA) Promotes integrated solutions to municipal solid waste management problems. http://www.wte.org

Intelligent Processing and Manufacturing of Materials http://mining.ubc.ca/ipmm

International Association of Plastics Distributors (IAPD) Represents the interests of companies worldwide that distribute and manufacture plastic materials, including sheet, rod, tube, pipe, valves, fittings, film, and related products. http://www.iapd.org

International Liquid Crystal Society (ILCS) http://scorpio.kent.edu/ILCS/

International Organization for Standardization (ISO) Provides information about ISO standards, publications, and meetings. (in English and French) http://www.iso.ch/welcome.html

International Organization for Standardization: ISO 9000 Guidelines and Tips This in-depth site, from Canada's Praxiom Research Group Ltd., translates the complex ISO 9000 quality system standards into plain English. http://www.connect.ab.ca/~praxiom/

Iron and Steel Society (ISS) http://www.issource.org/

JLI-Boston Executive Search Exceptional plastics industry head hunter. Excellent reputation according to top industry executives. http://www.jli-boston.com

Journal of Corrosion Science and Engineering http://www.cp.umist.ac.uk/JCSE/

Kluwer Academic Publishers Major worldwide publisher in various areas, including plastics. http://www.wkap.nl

Los Alamos National Laboratory (LANL) http://www.lanl.gov/

LSU's Libraries' U.S. Federal Government Agencies Page http://www.lib.lsu.edu/gov/fedgov.html

3M Provides a website for adhesives, tapes, and recloseable fasteners http://www.3m.com/bonding

Maack Business Services Provides updates on plastic costs, pricing forecast, and supply and demand. http://www.MBSpolymer.com

Manufacturers Information Net Home Page http://www.mfginfo.com

Manufacturing Technology Information Analysis Center Provides answers to manufacturing questions, promotes exchange of manufacturing technology information, and supports Department of Defense manufacturing technology programs. Sponsored by U.S. Department of Defense and operated by ITT Research Institute. http://mtiac.iitri.com

Martin Thomas, Inc./Marketing Services Major source for marketing services in plastics. http://www.martinthomas.com

Massachusetts Institute of Technology, Department of Materials Science and Engineeering http://www-dmse.mit.edu/

Materials Algorithms Project Source of algorithms useful for modeling material behavior. http://www.msm.cam.ac.uk/map/mapmain.html

Materials Properties Handbooks Operation Distributes the *Aerospace Structural Metals Handbook*, the *Structural Alloys Handbook*, the *Damage Tolerant Design Handbook*, and the *Composite Failure Analysis Handbook*. http://www.purdue.edu/MPHO

MatWeb Quick Search A materials information archive. http://www.matweb.com

MEMS Material Database (Microelectronic Mechanical Databases) http://mems.isi.edu/mems/materials/index.html

Metropolitan Washington Council of Governments (COG) A regional organization of Washington-area local governments that provides a focus for action and develops sound regional responses to a number of issues, including the environment. http://www.mwcog.org

MicroPatent, Patent and Trademark Information http://www.micropat.com

Milacron, Plastics Technologies Group Major world manufacturer of processing/fabricating machinery and auxiliary equipment that includes blow molders, coextruders, coinjection machines, extruders, injection molders, instrumentation systems, granulators, etc. http://www.milacron.com

Modern Plastics and Modern Plastics International Provides real-time news and updates on what is happening and also occurring into the future. http://www.modplas.com/

Molding Systems Formerly *Plastics World* magazine until 1997 when SME acquired it. It focuses on the plastics manufacturing and design engineering audience. Associated with the Plastics Molders and Manufacturing Association (PMMA) of SME. http://www.sme.org

MSDS Search Comprehensive source of information related to material safety data sheets. Access to one million MSDSs provided. http://www.msdssearch.com

Multiscale Materials Modeling Program http://multiscale.llnl.gov

National Association for PET Container Resources (NAPCOR) Facilitates the economical recovery of plastic containers, with an emphasis on PET, including U.S. recycling industry statistics and member company profiles. http://www.napcor.com

National Association of Corrosion Engineers (NACE) International (corrosion) http://www.nace.org

National Certification in Plastics Program This site of the Society of the Plastics Industry offers detailed information on its program to certify plastics machine operators in blow molding, extrusion, injection molding, and thermoforming. http://www.certifyme.org

National Environmental Information Service A clearinghouse of government environmental documents, including all U.S. Environmental Protection Agency and Occupational Health and Safety Administration documents, plus links to various chemical industry resources online. http://www.neis.com/neis.html

National Institute of Standards and Technology (NIST) http://nvl.nist.gov

National Plastics Center and Museum (NPCM) A nonprofit institution dedicated to preserving the past, addressing the present, and promoting the future of plastics through public education and awareness. http://www.npcm.plastics.com

National Textile Center, University Research Consortium http://ntc.tx.nesu.edu

National Tooling and Machining Association (NTMA) Represents some 2,700 U.S. companies that design and manufacture special tools, dies, molds, jigs, fixtures, gauges, special machines, and precision machined parts. This site includes a searchable buyer's guide and members directory. http://www.ntma.org

Naval Research Laboratory (NRL) http://www.nrl.navy.mil/

NDC Infrared Engineering Industrial gauging of measurement and control moisture, thickness, and basis weight. http://www.ndcinfrared.com

NIST Atomic Spectroscopic Database http://aeldata.phy.nist.gov/nist.atomic.spectra.html

NIST Databases distributed by Standard Reference Data Program http://www.nist.gov/srd/dblist.htm

Owens-Corning Provides a glass-fiber composite-material database, technology, and leadership regarding materials of constructions, processes, design data, and applications by markets. http://www.owens-corning.com:80/composites/

Pennsylvania College of Technology Education and training services. http://www.pct.edu/ttc/

Pennsylvania State University, Behrend Plastics Engineering Technology http://eetsg08.bd.psu.edu/degrees/plet.html

Plasnet A hub site for Australia's plastics industry. http://www.plasnet.com.au/

Plastics Bag Association (PBA) A 60-company consortium of the leading bag manufacturers and suppliers provides this information clearinghouse about plastic bags and the environment. http://www.plasticbag.com

Plastics Engineering Magazine The official publication of the Society of Plastics Engineers, the leading technical society of the global plastics industry. http://www.4SPE.org

Plastics Institute of America Education and research organization including on-site training. http://www.eng.uml.edu/~PIA

Plastics Mall Provides information on materials, equipment, services, processing services, etc. http://www.plasticsmall.com

Plastics Molders' and Manufacturers' Association (PMMA) A resource to plastics professionals in all industries from medical manufacturing to automotive. http://www.sme.org

Plastics Network Market-oriented supplier and service firm. http://www.plasticsnet.com

Plastics News Provides what's new today, such as industry in-depth stories, supplier search, resin pricing, story archives, rankings and listings of processors, market trends, viewpoints and opinions, and stock index. http://www.plasticsnews.com

Plastics Pipe Institute The major trade associations representing segments of the plastics industry focused on effective use of plastics piping. http://www.plasticpipe.org

Plastics Processors' Association of Ohio Promotes the cause of plastics processors in Ohio. http://www.ppaohio.org

Plastics Resource This site, a service of the American Plastics Council, contains extensive information on plastics and the environment. http://www.plasticsresource.com

Plastics Technology Daily online news provided regarding different information concerning primary and secondary equipment, tools and components for the industry, market research data, material properties and characteristics, and buyers guides. http://www.plasticstechnology.com

Polyisocyanurate Insulation Manufacturers' Association (PIMA) The national trade association that advances the use of polyisocyanurate (polyiso) insulation. http://www.buildernet.com/pima

Polymeric Materials Related Resources, Cornell

Injection Molding Program http://xenoy.mae.cornell.edu/polymer-info.html

Polymer Processing Institute An independent research corporation focused on polymer technology and related areas. http://www.polymers-ppi.org

Polymers Dotcom Basic guides to plastics, description of material properties. They claim to have the oldest and largest internet index to plastics. http://www.polymers.com/dotcom/polylink

Polysort Internet marketing experts for the plastics and rubber industries. http://www.polysort.com

Polystyrene Packaging Council Washington-based arm of the Society of the Plastics Industry that claims to be the primary resource for polystyrene information. http://www.polystyrene.org

Polyurethane Foam Association Provides information on key issues and product characteristics that may be of interest to flexible polyurethane foam users, researchers and academia. http://www.pfa.org

Rapid Prototyping and Manufacturing Institute http://rpmi.marc.gatech.edu

Rapra Technology Ltd. Shawbury, England-based Rapra is an independent, international organization providing information and consulting expertise on all aspects of plastics and rubber. http://www.rapra.net

Rensselaer Polytechnic Institute, Research Centers http://www.eng.rpi.edu/WWW/Research/centers.html

Rome Laboratory (RL) Air force plastics and composites research laboratory. http://www.rl.af.mil

Sandia National Laboratory (SNL) http://www.sandia.gov

SciPolymer Database http://www.esm-software.com/scipolymer

Service Corps of Retired Executives (SCORE) A volunteer organization offering counseling and seminars on problems related to the operation of a small business. Counseling is free but seminars have a nominal fee. http://www.score.org

Society for the Advancement of Material and Process Engineering (SAMPE) An international professional member society that provides information on new materials and processing technology for scientists, engineers and academics. http://www.sampe.org

Society of Automotive Engineers (SAE) http://www.sae.org

Society of Plastic Engineers (SPE) Helps individuals in the plastics industry attain higher professional status through increased scientific, engineering, and technical knowledge. http://www.4SPE.org

Society of the Plastics Industry, Inc. (SPI) Promotes the development of the plastics industry and enhances public understanding of its contributions, while meeting the needs of society. http://www.plasticsindustry.org

Society of the Plastics Industry Structural Plastics Division This unit of the Washington-based Society of the Plastics Industry has its own website, with a member company index and content geared toward molders and designers. http://www.structuralspi.org

SGS International Certification Services, Inc. Certification, testing, standards. http://www.sgsicsus.com

Solid Waste Association of North America (SWANA) Serves individuals and communities responsible for the management and operation of municipal solid waste management systems. http://www.swana.org

Spirex Corp. Worldwide specialist and innovator in the design and manufacture of plasticator screws. They provide fabricated part quality with a high rate of profitable productivity. http://www.spirex.com

SRI Consulting, subsidiary of SRI International Provides comprehensive, accurate, and timely coverage of the international chemical industry. http://www.cbrd.sriconsulting.com

Superplasticity on the Web, Michigan Technical University http://callisto.my.mtu.edu/superplasticity.shtml

Supplier Search Offered by Plastics News and Supply Base Inc., Supplier Search is an interactive, global database designed to help users find and qualify plastics industry processors and suppliers. Some sections also include detailed Request for Quote forms. http://www.pnsuppliersearch.com

Thermal Spray Society http://www.asm-intl.org/tss

Tube Council of North America This New York trade group represents makers of plastic, laminate and metal tubes for dentifrice, cosmetic, pharmaceutical, household/industrial and food applications. http://www.tube.org

TUV America Inc. Certification, testing, standards. http://www.tuvglobal.com

U.K. EPS Recycling Information Service Featuring a directory of companies recycling expanded polystyrene in the United Kingdom, plus related information. http://www.eps.co.uk

Underwriters' Laboratories Inc. Information on the UL Mark and on related standards, services, directories, etc. http://www.ul.com

University Microfilms International (UMI) Search 1.4 million dissertations and theses. http://www.umi.com

University of Akron College of Polymer Science and Engineering http://www.polymer.uakron.edu

University of California at Berkeley Library http://www.lib.berkeley.edu/ENGI/net.html

University of Delaware Center for Composite Materials http://www.ccm.udel.edu

University of Iowa at Ames, Materials Preparation Center http://www.external.ameslab.gov

University of Massachusetts at Lowell, Plastics Engineering Department and Division of Continuing Education New England's largest public educator in the areas of engineering and science. Its Plastics Engineering Department, established in 1954, is a major leader in the field of plastics. http://www.uml.edu/dc

University of Rochester, Institute of Optics http://www.optics.rochester.edu:8080

University of Southern Mississippi, Department of Polymer Science http://www.psrc.usm.edu

University of Wisconsin at Milwaukee Strong plastics industry-related seminars. http://www.uwm.edu:80/dept/ccee/

U.S. Environmental Protection Agency (EPA) The federal agency's home page offers a collection of resources, including information on regulations, grants, and programs. http://www.epa.gov

U.S. Greenbuilding Council Coalition of 275 leading international organizations with the mission to accelerate the adoption of green building practices, technologies, policies, and standards. http://usgbc.org

U.S. Patent and Trademark Office http://patents.uspto.gov

Vermont SIRI MSDS Collection Provides chemical search on toxicity or hazardous reports and data. http://www.hazard.com/msds/index.html

Vinyl Institute This site provides information on environmental issues and links to member companies and other allied organizations. http://www.vinylinfo.org

Vinyl Siding Institute (VSI) The only organization dealing with the major issues of the vinyl siding industry. http://www.vinylsiding.org

Vinyl Toys Several international PVC trade bodies—all hot linked from this home page—joined forces to create this site, which they describe as "an information resource on the safety and benefit of vinyl toys." http://www.vinyltoys.com

Waste Policy Center The Waste Policy Institute deals with environmental and policy issues related to both business and governmental organizations. http://www.winporter.com

Welding Society http://www.aws.org

Welex Inc. World famous equipment manufacturer of standard extruder sheet lines with totally interchangeable precision components. They provide high output rates with profitable performance. http://www.welex.com

Wilmington Machinery Blow-molding machinery builder for the industry. http://www.wilmingtonmachinery.com

World Packaging Organization This site, known as PackInfo-World, serves as a global resource for information about your packaging needs. http://packinfo-world.org/wpo/

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