Guidelines on Health Aspects of Plumbing

by Floyd Taylor and William Wood

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ABSTRACT

Guidelines have been prepared for plumbing services and water, sewerage and health authorities. They have been written with the needs of developing countries especially in mind.

Part one concerns the drawing up and administration of a code of plumbing practice. Such a code consists of an ordinance and plumbing standards. The latter is covered in part two. Standards and regulations for plumbing systems in single, multiple and multistorey dwellings are dealt with, as well as those for dual water systems and stormwater drainage. The third part gives general notes on special subjects such as protective devices materials and intermediate sanitation.

Although the guidelines will have to be adapted to suit specific country's requirements, the need for an institutional and legislative framework is emphasized in order to protect installations and consequently the health of the consumer.

Keywords: plumbing / plumbing code / guidelines / water authorities / sewerage / developing countries / urban areas / legislation / plumbers / training / dual water supply systems / storm drainage / water conservation / pipe materials / public toilets / fixtures / disinfection / health aspects.

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COMMUNITY WATER SUPPLY
AND SANITATION

GUIDELINES ON HEALTH ASPECTS OF PLUMBING

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acknowledgement

In response to an identified need in developing countries, WHO initiated the preparation of this document on Guidelines on Health Aspects of Plumbing.

From his original draft Mr. Floyd Taylor, in collaboration with Mr. W. E. Wood, developed the document incorporating comments and suggestions made by a panel of reviewers.

Staff work on the document at WHO Headquarters in Geneva was done by Mr. R. E. Novick and Dr. R. C. Ballance.

An agreement was entered into by which the International Reference Centre for Community Water Supply and Sanitation, WHO Collaborating Centre, would undertake the finalization of the draft document for printing and dissemination through its Technical Paper Series.

The IRC is grateful to Dr. Ballance and Mr. Wood for their guidance and help in the painstaking editing and polishing work of the document, the contribution of Mrs. Cindy Maurer who produced intermediate copies and the final copy of the text is especially appreciated.

The Guidelines will hopefully be a useful contribution to countries in their pursuit of national goals within the context of the International Drinking Water Supply and Sanitation Decade.

T. K. Tjiook, I.R.C.

contents

preface

Of recent years there has been an increasing awareness of the part played by the availability of safe and ample water supplies, and by the prompt removal and sanitary disposal of liquid wastes, in the improvement of the health and wellbeing of people everywhere. As a result governments throughout the world have undertaken programmes for the provision of water in adequate quantities and for the construction of sewerage and other sewage disposal facilities, especially in urban areas, where the hazards of inadequate sanitation put the health of a great number of people at risk.

The World Health Organization, together with other international bodies, has been active in encouraging and assisting national authorities both in the setting up of appropriate water and sewage authorities and in the planning and implementation of construction projects. Much still remains to be done, but progress in many countries has been steady and is continuing.

As a consequence of national programmes many towns and cities in developing countries now have good water supply systems, delivering adequate quantities of high-quality water through a network of distribution mains under the control of a competent water authority. Many, too, have systems of sewerage and sewage disposal operated by an authority that may or may not be the same as that supplying water.

In some instances, however, a link is missing in the chain of delivery and removal. Water is provided in the mains; waste is collected through sewers. For these services to be useful to individual consumers there must be pipes leading from the mains to the properties concerned, internal pipework and fittings within the buildings, and drains to convey the used water and human wastes from the buildings to the sewers. Together these pipes, fittings and drains constitute "plumbing" - the subject of the present guidelines.

Plumbing systems are normally installed and maintained by private enterprise rather than by the water or sewerage authorities, but these authorities cannot afford to be indifferent to the way in which the systems are designed, constructed and operated. Leakage from service pipes of inferior material or workmanship can waste water as easily as can a faulty main; infiltration into badly jointed drains can overload sewers and sewage disposal works. More importantly, faults in the design of interior pipework or fittings can result in the contamination of the water in the mains themselves, putting at risk the health of other consumers in the neighbourhood. Thus health authorities must exercise sufficient control over the design, construction, materials and workmanship of plumbing on private property and public areas to ensure that the health of the public is protected. Water and sewerage authorities equally have an interest in good plumbing practice to protect water quality, to prevent wasteful leaks in water service lines, and to minimize the risk of surcharge to sewage flows.

The achievement of this control involves laying down standards and regulations contained within a comprehensive code of practice, and supporting this code with legislation and with an inspection mechanism to secure compliance with its provisions. A system of examination and certification of the craftsmen who will carry out plumbing work should be instituted, and, by implication, adequate training facilities should be available to enable these plumbers to become sufficiently proficient to operate in accordance with the code.

The present guidelines have been prepared with these aims in mind. They are divided into three parts. First are some suggestions as to the drawing up and administration of a code of practice of this nature. The second part contains some practical and technical details of plumbing systems to be installed in accordance with the code. In the third part are some general notes on special problems, whose importance will vary with the conditions prevailing in different countries. The degree of detail with which any one of these problems should be dealt with by national codes will be a matter of judgement in each case.

It is not intended that the guidelines should be taken as a rigid set of standards. Every country will need to adapt its requirements to suit its existing administrative and physical conditions; what is emphasized is the necessity of having some framework that will permit authorities to protect their installations and, in consequence, the health of their consumers. In the same way, the second part of this publication is not meant to serve as a complete textbook on plumbing, but rather as a reminder of those design aspects that have particular health implications and should therefore be subject to regulation and control for the sake of the population as a whole. The reader is referred in the bibliography (Annex 5) to actual codes that have been adopted in various countries. A study of the codes in question is recommended before new ones are formulated elsewhere.

It is hoped that these guidelines will be found helpful both to those responsible for providing plumbing services and to the authorities under whose jurisdiction they operate. Although many of the details are applicable to all types of community they have been written with the needs of the developing countries especially in mind. Information has been collected and compiled from a wide variety of countries, and the original draft was circulated to 34 reviewers in different parts of the world (see Annex 1), many of whose suggestions have been incorporated into the final version of these guidelines.

part 1

code of plumbing practice

1. the necessity for a code of plumbing practice

The objective of a public water supply is to provide all consumers with a continuous, ample supply of good-quality water in a convenient manner and at a price which each can afford. This usually involves extracting, treating, storing and transporting water from a natural source and distributing it through a system of mains that pass within a reasonable distance of the premises to be served.

To maintain the quality and quantity of water within these distributing mains requires continual supervision, operation by skilled staff, and recurrent expenditure, which is normally borne by the consumers in approximate proportion to the quantity of water delivered. As a result of quality checks, good management and control of wastage, the water within the mains should be safe and adequate for all domestic purposes and relatively cheap.

Systems of management vary widely in different parts of the world. The waterworks operating body may be a local authority, a government corporation or department - or even a private company. One characteristic these bodies normally have in common is the limitation of their direct responsibility to the water supplied in the mains network; it is for the owners of the properties concerned to convey their supply from a point near the distribution mains into their own premises and to circulate it to drawoff points within the buildings.

The provision of a safe and amply supply of water within the house is recognized as an essential factor for healthy living; it is also regarded as one of the concomitant amenities of civilized life. Almost as important, especially in crowded urban areas, is the prompt removal of human and domestic wastes from the points at which they are generated, and their conveyance, treatment and disposal at a safe distance and in a sanitary manner. Hence sewerage and sewage disposal are becoming more and more regarded as inseparable adjuncts to a public water supply, even though in many cases the sewerage system is constructed, operated and managed by a separate department of the water supply authority or by a different body altogether. Usually the management of wastes disposal is the responsibility of a local authority, such as the town council, which provides the service and collects the charges from its customers.

There is one particular parallel between water supply and wastes disposal. Liquid wastes are collected through a network of sewers, which constitute the limit of responsibility of the management body. It is up to the owners of the properties concerned to collect the wastes within the building in which they were generated and convey them to the public sewer.

Thus, for every property, between the point at which a public body supplies water (at or near the distribution main) and the sewer where the same or another public body receives the wastes for disposal there are, in effect, two privately owned (or sometimes publicly owned - as in the case of municipal buildings) systems of pipes - one conveying water and the other wastes - which pass underground, into and within the building, and come close together at sanitary fittings such as water-closets, sinks or baths. These pipes, internal and external, together with the fittings themselves, are termed the plumbing systems of the property.

Modern plumbing practice, as regards design, materials and workmanship, has been developed to ensure that there is no interconnexion between the water supply and the waste removal systems, that hazards to the health of the occupants and to the structure of the building are eliminated, that the elements of the plumbing system are durable and protected from accidental damage, that wastage is eliminated, and that the system functions efficiently. If such practice is not observed the ill effects may not be confined to the premises concerned but may also adversely affect the public services to which the plumbing is connected, even to the extent of jeopardizing the health of other consumers.

Such dangers are enhanced in industrial and commercial premises, where dual water systems, circulating pumps, toxic wastes and other factors have to be taken into account, in multi-storey buildings, where booster pumps are employed to increase the mains pressure, and in other cases of special use. However, even normal single-family domestic buildings can present health hazards to both occupants and neighbours if faulty plumbing is permitted.

The risks of mains contamination are greatest when the supply pressure fluctuates or the service is intermittent. This is one of the reasons why the deliberate interruption of supply (usually on the false premise that consumption and waste are likely to be reduced in an intermittent service) is nowadays regarded as a dangerous practice, to be avoided at all costs by an efficient water undertaking. Nevertheless, even in the best-operated public supply, circumstances will arise in which mains have to be shut off for cleaning, maintenance or repair, causing a lowered or negative pressure in the services connected to them. Under these conditions pollution can be drawn into the public supply from faulty plumbing on private property. The danger is not an imaginary one as can be shown by records of disease outbreaks in many parts of the world, the causes of which have been traced to this source.

Leakage and wastage of water represent a major recurrent expense to many water supply undertakings. While leaks in the public mains system can be minimized by systematic inspection and maintenance by the authority concerned, it is more difficult to trace and remedy leaks on private property. A relatively small (3 mm) leak in a service pipe, or a dribbling tap, under normal working pressure can waste 340 l (90 US gal; 75 UK gal) per day - the amount required to supply the needs of a family of three. A multiplicity of leaks of this nature can cost the supplying authority a substantial and continuing amount, which can be minimized if the materials and workmanship used in the installation of plumbing systems are of sufficiently high standard.

Similarly, leakage into drains (infiltration) can lead to the overloading of sewers and sewage disposal works, with consequent additional expense to the sewerage authority which will also be concerned with other precautions in plumbing systems. Measures must be taken to exclude materials that can choke sewers, or those of an explosive, flammable, corrosive or toxic nature that may be potentially dangerous to the public, or may interfere with the purification processes at the disposal works. Again, such dangers are particularly associated with commercial and industrial premises, but cannot be ignored even in ordinary domestic systems.

Public health authorities have a particular interest in the plumbing of buildings used by large numbers of people, such as schools, lodging-houses, hotels, public baths, transport termini, and other places of assembly. Lack of hygiene in such establishments can lead to disease transmission and outbreaks on an epidemic scale, so sanitary fittings must be designed, installed and maintained in such a way as to facilitate cleanliness at all times, and to reduce the incidence of insects or rodents that might carry disease. Special precautions are necessary in hospitals, laundries, and premises where food and drink are processed, stored or served to the public.

Thus there are three bodies that have a direct interest in ensuring that plumbing systems conform to modern hygienic standards - namely the water supply, sewerage and health authorities. In actual practice the supervision of new plumbing installations is often the responsibility of a fourth agency - the building inspectorate - whose prime duty is to ensure the stability of the particular premises in which the system is installed and the safety of its occupants. If all aspects of plumbing are to be regulated and public as well as private health hazards are to be minimized, it is important that all the relevant considerations should be combined into a single code of practice that will meet the requirements of all the bodies concerned.

These present guidelines contain suggestions for items that might be incorporated into such a code of practice, together with some notes as to the reasons for each and practical details of their implementation. They are not intended as rigid standards applicable universally, nor are they claimed to cover conditions to be found everywhere. It is hoped that they will encourage and assist the appropriate authorities in countries having no plumbing code to formulate one to suit their own particular circumstances. It is also hoped that the guidelines will be helpful to those who have to administer or implement such a code, to those who design plumbing systems and, perhaps most important of all, to those craftsmen who actually carry out the work - the plumbers themselves.

2. the principles of plumbing

Plumbing is, basically, an application of the science of hydraulics to convey water to, and wastes from, internal fixtures of a building. The laws of hydraulics are immutable and universal; unless a plumbing system is designed in accordance with them it will not work.

Certain other principles, or objectives, of a good plumbing system may be defined. Although they may not all be immediately attainable they should be regarded as goals to be achieved wherever possible, and as soon as circumstances permit. They are equally applicable to countries in all parts of the world, being based on the need to preserve the health, safety and wellbeing of the people served.

PRINCIPLE NO. 1 EVERY OCCUPIED BUILDING SHOULD HAVE AN INTERNAL WATER SUPPLY.

It is recognized that this is an ideal far from attainment in many places, but the evidence that a water supply within the home has a profound effect on the health of the occupants is so strong that this objective should be given priority. Interim measures, based on public standposts and communal facilities, are discussed later in these guidelines, but they should always be regarded as an intermediate stage toward the realization of this first principle.

PRINCIPLE NO. 2 WATER, WHEREVER SUPPLIED FOR DRINKING, DOMESTIC OR CULINARY PURPOSES, SHOULD BE SAFE AND POTABLE AT ALL TIMES.

On the assumption that the quality of the water provided through the public mains is subject to control to ensure that it is safe and wholesome, nothing in the plumbing system should be permitted that might degrade it in any way. It must be protected from interconnexion with unsafe sources or with waste-water systems, from the hazards of back-flow or back-siphonage, and from contact with unsuitable plumbing materials that might impart contamination.

PRINCIPLE NO. 3 WATER SHOULD BE CONSERVED.

Piping systems and plumbing fixtures should be so designed, maintained and used as to consume the minimum quantity of water consistent with proper performance and cleaning.

Waste must also be avoided by protection of pipes and fixtures against corrosion and accidental damage, including that caused by frost.

PRINCIPLE NO. 4 WATER SHOULD BE SUPPLIED THROUGH A SUITABLE NUMBER OF ACCESSIBLE AND HYGIENIC FIXTURES.

Every self-contained family unit should have, as a minimum, one water-closet, one wash-hand-basin, one kitchen sink and one bathtub or shower. Other buildings, whether used for habitation or other purposes, should be provided with an adequate number of fixtures in accordance with their respective needs, as discussed later.

All plumbing fixtures should be made of durable, smooth, nonabsorbent, and corrosion-resistant material, so designed as to be easily cleaned, free from concealed surfaces that could become fouled, and incapable of contaminating the water supply by back-siphonage. They should be so sited and spaced that they are accessible for the intended use and for cleaning, and that walls and other surfaces which may become accidentally fouled during the use of the fixture are equally accessible for cleaning.

PRINCIPLE NO. 5 WASTES SHOULD BE PROMPTLY REMOVED AND DISPOSED OF HYGIENICALLY.

Wastes should be removed rapidly from each fixture by a system of drain-pipes that will prevent any further contact with them within the building.

Wherever a public sewer exists within reasonable distance of the premises the method of disposal should be by connecting the building drain to this sewer. In cases where no such sewer exists, disposal should be through an approved method of treatment, such as a septic tank, so located as to cause no nuisance either to the occupants of the building or to those of neighbouring properties.

In cases where the use of chemical closets is approved, adequate arrangements must be made for the sanitary disposal of sullage water (i.e., the wastes from other fixtures, such as sinks or baths), as well as the residue from the chemical closet itself.

Every fixture, including a wall-mounted tap, should be provided with drainage facilities to prevent the accumulation of waste water and spillage, even though this may be uncontaminated.

PRINCIPLE NO. 6 DRAINAGE SYSTEMS SHOULD BE OF ADEQUATE SIZE AND CLEANABLE.

Drains should be of adequate capacity, and should be so designed, constructed and maintained as to convey wastes rapidly from the building without fouling, depositing solids, or clogging. They should be constructed with adequate, easily accessible cleanouts or manholes so arranged that the pipes can be readily cleaned.

PRINCIPLE NO. 7 LIQUID-SEAL TRAPS SHOULD BE PROVIDED.

Each fixture, or group of fixtures, connected to the drainage system should be equipped with a liquid-seal trap, so designed and installed as to be proof against back-siphonage, aspiration or the forcing of seals. The depth of liquid in each seal must be adequate to prevent the emission of odours and gases, and the ingress of insects or rodents from the sewer into the premises.

PRINCIPLE NO. 8 ALL DRAINS SHOULD BE ADEQUATELY VENTILATED.

Every drainage system should be so designed and constructed that adequate quantities of air can circulate through every pipe, thus enabling the system to function properly and protecting the liquid seal of the traps. The uppermost part of the drainage system should be connected to a ventilating pipe of adequate size, discharging above roof level in such a position that the return of foul air to the building is prevented.

PRINCIPLE NO. 9 DELETERIOUS SUBSTANCES SHOULD BE EXCLUDED FROM SEWERS.

Suitable precautions should be taken to exclude from the drainage system any substance which may clog (or accentuate the clogging of) pipes, produce explosive mixtures, corrode or otherwise damage pipes or their joints, or which can endanger workers on the public sewer system or interfere with the process of sewage treatment.

PRINCIPLE NO. 10 PRECAUTIONS SHOULD BE TAKEN AGAINST BACK-FLOW OF SEWAGE.

Drainage systems should be so designed and constructed that in the event of back-flow from the public sewers, due to flood, blockage or any other cause, such sewage cannot enter the building.

PRINCIPLE NO. 11 BUILDING CONTENTS SHOULD BE PROTECTED FROM THE EFFECTS OF MALFUNCTIONING OF THE PLUMBING SYSTEM.

Precautions should be taken against damage to the property, or danger to the health of its occupants, in the event of malfunctioning of the system. Fittings should be provided with adequate overflow capacity. Roof tanks and other hidden elements of the system should be similarly provided with overflows discharging in such a way as to act as a warning.

Food storerooms within the building should be so sited that any leakage or back-flow in the drainage system cannot contaminate their contents. In the case of industrial or commercial premises where food is processed or prepared, or where sterile goods or similarly susceptible materials are stored or handled, additional precautions should be taken by indirect connexions of the internal fixtures t the plumbing system.

PRINCIPLE NO. 12 ADEQUATE LIGHTING D VENTILATION SHOULD BE PROVIDED FOR ALL FIXTURES.

Rooms in which water-closets nals or similar fixtures are sited should be properly lit ar ventilated. No such fixture should be permitted in a room used living, working, food preparation or other such purposes.

In the case of industrial or commercial premises or public buildings containing rooms where food and drinks or other material for human consumption are handled, stored or prepared, no watercloset or urinal should open directly from such a room, but should be separated by an adequately ventilated lobby or passage.

Other fixtures, such as sinks, wash-hand-basins and baths, should be so sited within the building that the lighting and ventilation are adequate to ensure their safe and hygienic use.

PRINCIPLE NO. 13 A HOT-WATER SYSTEM IS DESIRABLE IN ALL DOMESTIC PREMISES.

Adequate means of heating water and distributing it to all plumbing fixtures which normally require hot water for their proper use should be regarded as a desirable amenity in all habitable buildings. Equipment for heating and storing heated water should be so designed and installed as to guard against dangers from explosion or overheating, and pipes used for the conveyance of hot water should be of materials suitable to withstand the temperature of their contents.

PRINCIPLE NO. 14 PLUMBING MATERIALS AND WORKMANSHIP SHOULD BE OF ACCEPTABLE STANDARDS.

Pipes, joints, fixtures and other elements of a plumbing system should conform to accepted quality standards, and should be sufficiently durable to give satisfactory service over a long period.

Only craftsmen who have been properly trained and have given evidence of their competence should be responsible for the installation of plumbing systems.

PRINCIPLE NO. 15 PLUMBING SYSTEMS SHOULD BE PROPERLY TESTED BEFORE BEING PUT INTO SERVICE.

Tests suitable for various types of plumbing systems should be specified by the water, sewerage and other authorities concerned, and no system should be put into service until such tests have been satisfactorily completed.

PRINCIPLE NO. 16 PLUMBING SYSTEMS SHOULD BE PROPERLY MAINTAINED.

In the case of large or complex systems, or where public use or the handling of food for sale is involved, the health (or other) authority may require periodic inspection and retesting as a condition for approval.

It should be incumbent on the owner of any plumbing system, irrespective of its size or purpose, to identify and to repair promptly any fault that may develop, whatever its cause.

3. formulation of a plumbing code

Plumbing codes vary widely in formulation from country to country, but in general they cover two broad ranges of subject. First, they deal with the legislative powers required to enforce compliance with standards of design, materials and workmanship, and, secondly, they provide a definition of those standards.

Normally the first part - referred to in these guidelines as the "plumbing ordinance" - requires governmental sanction or a specific law enacted by the legislature conferring statutory powers on a particular authority to formulate and enforce a code of practice. In certain cases the same effect may be achieved by the delegation of ministerial powers, or by some other political device. The common factor is that the responsibility (as well as the power) of implementation is vested in a single identifiable body, whose limits of authority are clearly specified.

This concept of undivided responsibility is particularly important since, as has already been discussed, there may be several separate authorities whose criteria need to be met. Water, sewerage, health and building interests have already been mentioned; such other public concerns as the food and drug inspectorate, the ministries for tourism, housing, and industry, and a port or railway authority may all have standards to which they require adherence within their particular sphere of competence. A plumbing code should be sufficiently comprehensive to include all these considerations, but at the same time the owner or builder of the premises in which plumbing is to be installed should have to deal with, and satisfy the requirements of, one body alone.

One way in which this can be achieved is by the formulation of a national code that applies throughout the country, compliance with which is enforced by a government department or ministry. In countries in which responsibility is delegated to State, provincial or local authorities, an alternative method is the preparation and publication, at a national level, of model standards and regulations incorporating the requirements of all interested authorities. These standards (which, incidentally, will periodically need reviewing and updating) can be adopted in whole or in part by local authorities each of which is vested, by separate ordinance, with the responsibility and power to require compliance with the standards within their particular area. In some cases, notably in the larger cities, it may be advantageous to set up a joint committee - a "board of plumbing examiners" - or some other tribunal representing all interests concerned, to advise the local authority and to adjudicate in complex proposals or disputes arising out of a conflict of interests.

With the reservation that different national political and administrative systems may call for other approaches, these guidelines have been drafted on the basis of a code of practice incorporating:

(1) A plumbing ordinance designating a local authority as the "authority having jurisdiction", with power and responsibility to enforce compliance with standards of design, materials and workmanship in any plumbing system to be installed within their area of administration.

(2) A detailed set of standards and regulations, related to a nationally approved model, to be enforced under this ordinance.

Among the powers that may be granted under the ordinance are the registration and licensing of plumbers (as discussed in Chapter 4), the right of entry for the purpose of making inspections, the establishment of conditions under which permits for plumbing installations may be granted, the right to charge fees (in accordance with an approved scale) for the granting of licences or permits, and the authority to take action in the courts in the event of violations.

One possible form of this ordinance is suggested in Chapter 6, but there may be wide variations even within the same country, depending on such factors as whether the "authority having jurisdiction" is also the water and sewerage authority, whether a single municipality or a State or provincial authority covering a number of communities is involved, whether there is a national system for the training and examination of plumbers, whether the authority concerned also has responsibility for the administration of building bylaws, and so on.

The first action of the newly designated "authority having jurisdiction", after promulgation of the ordinance, must be the formal adoption of the standards and regulations which it intends to enforce, thus completing the formulation of its code of practice.

Since the smoothness and efficiency with which it will be able to implement the code will depend materially on the way the public cooperates, the authority should have paved the way to its acceptance by property owners, builders, plumbers, and other interested parties. Press articles and talks detailing the health implications are ways in which the support of the general public may be enlisted, property owners may be convinced that the value of properly plumbed premises can increase by more than the outlay involved while plumbing craftsmen may become enthusiastic supporters of the code when they are convinced that it protects them from being unfairly undercut by unskilled competition. It may be considered desirable for local interests of this nature to be represented on the joint committee (referred to earlier), or to be consulted by that committee when the standards for local enforcement are formulated.

4. training and registration of plumbers

The efficiency and the length of useful life of any plumbing system will depend upon three factors - the degree of excellence of its design, the quality of the materials with which it is constructed, and the skill and conscientiousness of the plumbers who actually install it. The second part of the plumbing code lays down the principles of design, and the approval by the authority of the plans for a new system implies that it is satisfied that these principles have been complied with in the proposal. The quality of the materials used may be safeguarded by insisting on adherence to national or international specifications, which should also be cited in the code.

Ensuring that the workmanship is of a high standard may not be so straightforward, even though inspections and tests of the work may be carried out at certain stages by the staff of the authority. Considerable reliance has to be placed on the integrity and ability of the plumber, especially as a large part of the completed work will not be visible, being below ground, under floors or behind the walls of the finished building. It is neither practicable nor economical to require the authority to employ a technical staff numerous enough to inspect all plumbing operations at all stages of installation.

Plumbing is a craft calling for theoretical knowledge allied to manual skill. Admission to the trade is usually by apprenticeship lasting five to seven years; an alternative is a course at a technical training institution, followed by a reduced period (usually three years) as an improver gaining practical experience under direction. At the end of the approved period as apprentice or improver the entrant may take a theoretical and practical examination, upon the passing of which he may be designated a "journeyman plumber", capable of working on his own without supervision and able to take responsibility for the work of less skilled men (e.g., drain-layers) operating under his direction.

A third grade of plumber is also recognized - namely, the "master plumber", who is a qualified journeyman with many years of experience, capable of overseeing the installation of complex systems, of supervising, inspecting and approving the work of others less experienced, and of accepting and training apprentices.

In general, authorities will accept a journeyman as responsible for straightforward plumbing installations, and will call for a master plumber to be in charge of large or complex systems. Apprentices and improvers are permitted to work on any type of plumbing provided that they are under the immediate direction of a qualified journeyman or master plumber who will himself take the responsibility for any shortcomings in workmanship that may result.

As an additional precaution against careless or negligent workmanship authorities may insist upon the registration and licensing of all plumbers operating within their areas; in some instances they may also insist upon a deposit or indemnity (to cover the cost of replacing defective work) before a licence is granted. Registration is dependent not only on evidence of qualification as a craftsman, but also on character, experience and reliability. The ability of the authority to revoke, or fail to renew, a plumber's licence is a powerful sanction against breaches of the code. Registration of plumbers in their appropriate grades depends on the existence of a recognized training syllabus and of a qualifying examination. Only a very large authority could hope to undertake training and conduct its own examinations. In any case a nationally accepted qualification (entitling the holder to local registration if the other conditions are complied with) encourages mobility and leads to better practice throughout the country. It is obvious, for instance, that a town installing a public water supply system for the first time would be most unlikely to find qualified plumbers among its own inhabitants, since work for such craftsmen has hitherto been lacking, and if there are no practising craftsmen there are no opportunities for new recruitment through apprenticeship.

There are several ways in which the problem can be solved. In some countries training courses are conducted by universities or technical training institutions which grant certificates of competence on successful completion of the course. The main objection to reliance on such certificates or diplomas alone is that they tend to stress the theoretical aspect of training and underemphasize the importance of subsequent practical experience.

In other countries a ministry of the national (or State) government, such as the public works department, ministry of industry, or the national water corporation, conducts training courses, holds examinations, and keeps its own register of qualified plumbers graded according to both practical and theoretical experience. A plumber whose name is on this register does not have to take a further technical examination to obtain a licence to practise (in his own grade) under any authority in the country.

Another type of examining body may be provided by the plumbing trade itself. A national guild or institute of plumbing may select its own examination board from among its most experienced members, set its own conditions for apprenticeship and its own training and examination syllabus, and award its own certificates of competence. A guild of this sort, primarily concerned with the standing and reputation of its members, and recognized by the national authorities as a fair and competent body, may be the most appropriate agency to compile and maintain a national register, inclusion in which would be an essential condition for being licensed by a local authority. Such a guild could also be of great assistance in the formulation, periodic review and updating of plumbing codes of practice, and might also provide an arbitration mechanism in cases of ambiguity or dispute.

In some countries a similar function is exercised by organizations having a wider range of interests, such as national sanitation foundations or building research institutes. In others a professional society (such as a waterworks association or engineering institution) may sponsor the training of craftsmen and award diplomas to those qualifying. Such organizations, whether guild, institute or society, can play a very useful part in upholding standards of design and workmanship, and it may well be advantageous for governments to encourage and support their foundation and continuance.

For simplicity, in the chapters that follow, one particular pattern of administration is assumed - a municipality as the "local authority having jurisdiction", a plumbing code based on nationally formulated model clauses, and a national plumbing association as a training and examining body. In countries where this pattern is inappropriate the general principles will still be found relevant and can be fitted into the prevailing administrative system.

5. administration of the plumbing code

The authority having jurisdication (referred to hereinafter as "the authority", for the sake of brevity) has certain responsibilities for ensuring that the code is properly implemented. These include:

(1) Inspection and approval of plans and specifications for all new plumbing work proposed within its jurisdiction.

(2) Inspection of new work to ensure that it is being carried out in accordance with the plans and with the code.

(3) Testing of new work on completion, and the issue of a certificate to the effect that such work has been satisfactorily completed.

(4) Periodic inspection and testing of existing systems where special hazards are present.

To undertake these responsibilities it is necessary for the authority to employ skilled and experienced staff; according to the size of the authority this may consist of a single sanitary engineer or a full inspection department. For convenience, the authority's technical or professional representative or representatives will be referred to as "the inspector", it being understood that this same man or department may also be responsible for other municipal duties such as the administration of building bylaws.

Within the code, the authority will set out its requirements regarding submission of plans and of other information relating to any proposed plumbing work. "Plumbing work" should be defined; not only should new systems be subject to the code, but also substantial replacement of, or changes to, existing systems. It is probably simpler to define those types of work that may be exempted from the need for approval (e.g., the repair or replacement of a single plumbing fixture, small domestic installations connected neither to a water main nor to a public sewer). The inspector should be prepared to give guidance in cases of doubt. Borderline cases are most likely to arise in industrial and similar premises, where temporary piping is subject to continual adjustment and realignment (the most important criterion here should be whether cross-connexion with unsafe sources is a possibility).

Normally the onus of making application to the authority is on the owner of the property concerned, but there is usually provision for a licensed plumber to apply on his behalf and at his request. Most authorities require applications to be made on standard forms, which they supply; this saves time by ensuring that essential items of information are presented in a recognizable and comparable manner. For single domestic installations the application is sometimes combined with proposals under the building bylaws, thus simplifying formalities both for the applicant and for the authority. Specimen forms are frequently annexed to model bylaw clauses as a guide to authorities contemplating the introduction of standardized application procedures.

One item of information required will be the name of the licensed plumber responsible for the work and his registration number. Some countries make an exception regarding domestic property where the work is to be carried out by the owner himself, but others regard this exemption as dangerous since unskilled installation may affect public supplies in ways already discussed.

Applications must be supported by plans, and the authority's requirements in this regard should be stated in the code. As in the case of application forms, plans relating to single domestic systems may often be combined with those relating to structures under the building bylaws. At the other end of the scale, proposals for multistorey apartment buildings or for industrial premises incorporating dual water supplies should be shown in considerable detail. To ensure that adequate information is given where required, and at the same time to avoid putting the applicants for small and straightforward systems to unnecessary trouble and expense, some compromise is called for. This may take the form of specifying in the code the theoretically desirable standards for plans to accompany applications, and at the same time giving the inspector discretion to relax these standards where this can be safely done without ambiguity.

Upon receipt of the application and plans these will be studied by the inspector, who will recommend the authority to approve them, or to reject them on the grounds that they do not comply with the code. It will make for good relations, and save delays, if the inspector is authorized to notify the applicant should he propose to recommend rejection, giving the grounds for his adverse comments, thus allowing the applicant the opportunity of making suitable amendments or of supplying additional information before the authority considers the proposal.

The authority (or its appropriate committee) normally meets periodically. To reduce delays in approving (or rejecting) an application it is desirable that the dates of the meeting, as well as the time-limit for the reception of applications by the inspector before the meetings are held, should be generally known. A maximum period should be stipulated within which the authority should give a decision one way or the other.

After the plans and applications are approved the plumber should notify the inspector (again special forms are often provided for this purpose by the authority) of the date when work is about to start. Later, similar notification will be required of the date when the completed work is ready for testing and approval. Between these dates the inspector should have the right to enter the premises at any reasonable hour to inspect the progress of the work and to examine any materials to be included. At the conclusion of any test (whether "intermediate" on part of the system, or "final" on the completed installation) the inspector should confirm in writing whether or not the findings were satisfactory.

The authority may provide its own apparatus for testing (e.g. pressure equipment, drain plugs) or it may require the plumber to supply his own. Where the authority's equipment is used it is common for the plumber to have to collect it, set up the test and return the apparatus after successful completion; sometimes a hire fee may be charged by the authority for this service. In the case of systems with potential public health hazards (e.g. premises where food or drink is processed, hotels and lodging-houses, and industrial premises having dual water systems) it may be a condition of the authority's approval that the plumbing system shall be retested, say every two years, and that such tests shall be witnessed by the inspector, who shall also satisfy himself that no cross-connexions or other violations of the code have occurred since the previous inspection and test.

Implementation of the code obviously involves the authority in certain expenses, notably for the staff engaged in processing applications, inspections of premises, testing of systems and so on, as well as office accommodation, printing, transport and other ancillary costs. In some countries these expenses are recovered from the applicants in the form of fees for particular services - e.g., for the issuing of a permit or certificate of approval, for witnessing a test on the whole or part of a plumbing system, or for registering a plumber. If such fees are charged they should be shown as a schedule in the code. They should be clearly distinguished from the fees or charges that may be levied by the water, sewerage or other authority for specific items of work - e.g., for making a connexion to a water main or sewer, for making good the highway surface after back-filling a trench, for clearing a septic tank, for accepting industrial waste into public sewers

Many countries prefer not to include the collection of fees as part of the code. Partly this is because they consider that the services described are provided to the public as a whole and should therefore be borne by the community as a whole. Another reason is that it is virtually impossible to produce a scale of fees where the amount charged is fairly proportioned in accordance with the service provided. But probably the chief objection is that the income likely to be received is often more than outweighed by the cost of extra staff and other expenses incurred in collecting and accounting for it.

There are certain details that may be included in the code that could be regarded as regulations emanating from authorities other than those responsible for plumbing standards. For example, it is usually considered most desirable that individual dwellings should each have a separate connexion from the water main and to the public sewer, but there are occasions, notably when crowded estates or properties remote from the highway are dealt with, when this requirement is relaxed - usually by way of a special agreement whereby those who share a combined service accept responsibility for a proportion of future maintenance costs.

Another detail that should be specifically defined is the boundary between public services and private plumbing. Where, as is so often the case, water mains and sewers are laid under the public highway it is common practice for the respective authorities to accept responsibility for the drain-pipes and service connexions which lie between the boundary of the property to be served and the public main or sewer. Practices vary: sometimes the authorities concerned install these pipes themselves and charge the applicant for the initial cost; sometimes the licensed plumber makes the connexion and lays the pipes, which the authority takes over on completion; sometimes the water authority provides an underground valve on a service line just inside the property boundary, from which point onwards the owner accepts responsibility. In the same way the sewerage authority may construct (or require to be constructed) a manhole on the border between private and public land.

It is difficult to say that any one of these practices is better than another under any particular circumstances, but the important point is that the one adopted should be clearly defined, preferably in the code.

One type of plumbing hazard that is very difficult to control is the temporary installation for a particular purpose which, because it is not part of a plumbing system or connected to conventional fixtures, is not subject to the requirement of plans submission. Nevertheless, such temporary installations can be at least as dangerous as permanent systems - the more so if they are not subject to the code as regards construction and use.

One of the most common purposes for which a temporary connexion is required is the provision of water during building construction. Hoses from standposts may be seen on building sites delivering supplies into tanks of muddy water in such a way that a drop in mains pressure could siphon the contents back into the public system. Hoses may also connect standpost and concrete mixer and provide water for various building processes. Sometimes temporary latrines for the builders' workmen are constructed with defective sanitary fixtures illegally connected to the main.

Hoses or other temporary piping may constitute a danger in other circumstances - at a garage, in a farmyard, on a fairground, watering a garden (especially when coupled to an insecticide sprayer), or cleansing a market or the interior of market vehicles. The plumbing approval will cover the permanent system, possibly including a perfectly legitimate external tap to which a hose may be connected, but normally the use to which the hose is put is not dealt with by the code. The only safeguard is the agreement between the water authority and the owner; payment is usually required for the water used, and the purpose of the hose specified when the payment is assessed. Rules for sanitary usage may be incorporated into the permit or agreement.

There is little point in formulating a code of practice or laying down standards if these cannot be enforced. Since the code incorporates, and is based upon, the plumbing ordinance, any contravention f any of the provisions constitutes a breach of the law, punishable by law after due action to establish the offence, identify the offender, and bring him to court. This is obviously a clumsy process, and sufficiently time-consuming to ensure that comparatively minor breaches would be rarely, if ever, followed up. Even if successful action were taken against an offender the penalties imposed by different courts for similar breaches would be liable to wide variation.

It is common practice, therefore, in those countries where the legal system so permits, to annex to the ordinance a schedule of penalties related to violation of particular clauses. In case of dispute the matter may be taken to the courts, or settled by arbitration where the offence is of a technical nature, but the imposition of a fine commensurate with the gravity of the breach of the code involved may make it unnecessary for the authority to have recourse to the more drastic sanctions within its powers - i.e., withdrawal of the licence of a practising plumber, refusal to permit connexion of a new system to the public mains, or disconnexion of an existing installation where the contravention of the code has been shown to exist.

Examples of offences for which statutory penalties are applied in various countries include the following: altering plumbing systems without notifying the authority; allowing water to be wasted or contaminated through misuse or neglect of pipes or fittings; using water for unauthorized purposes; interfering with valves or other apparatus belonging to the authority or with the operation of any meter upon which water charges are based; and refusing admission to the authority's inspector (after due official notice has been given) or obstructing him in his duties.

6. contents of the plumbing ordinance

Legislative systems differ so widely from one country to another that it is virtually impossible to suggest a model ordinance that would be acceptable everywhere. The following are examples of the type of clauses that might appear in a government ordinance designating the town council of the municipality of XYZ as the "authority having jurisdiction" over plumbing in its area.

Plumbing Ordinance

1. The town council of the municipality of XYZ (hereinafter referred to as "the authority") is hereby designated as the authority having jurisdiction over all plumbing systems within the boundaries of the township and within such areas lying outside the boundaries as are served by the public water supply system of the municipality of XYZ.

2. For the purposes of this ordinance the words "plumbing systems" shall be taken to mean all water pipes, drains, sanitary fixtures and other installations, whether within or outside buildings, connected or capable of being connected in the future, directly or indirectly, to a public water main or to a public sewer, irrespective of whether these plumbing systems are publicly or privately owned.

3. The authority shall lay down such standards and regulations as it considers necessary to ensure that all plumbing systems within its jurisdiction are designed, installed and maintained in accordance with accepted sanitary principles. Together with the present ordinance these standards and regulations shall comprise the "plumbing code of practice" of the municipality of XYZ (hereinafter referred to as the "the code").

4. The authority shall administer the code, for which purpose it shall engage such staff or assistance as is necessary and shall take such actions as may be necessary and reasonable to obtain compliance with its

provisions, as regards both plumbing systems already existing within its area and those to be installed at any time in the future.

5. No person shall construct, install, extend or materially alter any plumbing system without making formal application to, and receiving formal approval from, the authority. Contravention of the code will be sufficient grounds for approval to be withheld.

6. The authority shall maintain a register of persons qualified under the regulations of the examining board of the national association of plumbers who have applied to have their names entered therein. The authority may grant a licence, at its discretion, to anyone so registered to become a "licensed plumber", after it is satisfied that such person is capable, of good repute, and familiar with the provisions of the code. Licences of a grade commensurate with the applicant's qualifications and experience shall be granted for a fixed period of years, after which they may be renewed after reapplication, but the authority shall have the power to revoke or terminate a licence in the event of bad workmanship or deliberate breach of the provisions of the code. In the event of a dispute regarding the issuing, renewal or termination of a plumber's licence, such dispute shall be referred to an arbitrator, nominated by the incumbent president of the national association of plumbers and acceptable to both parties, whose decision shall be binding.

7. Except where the authority shall agree in writing to other dispositions, only a licensed plumber shall be authorized to be responsible for the construction, repair, alteration or removal of pipes, valves, drains or other appurtenances of any water supply or drainage system (including storm drainage discharging into a public sewer or watercourse) in any building or on any land. Only a licensed plumber may make a connexion to a public water main or to a public sewer, and he shall be responsible for giving notice to the water and sewerage authorities of the intention of making such connexion and for satisfying any requirements of those bodies.

8. The authority may require any plumber to whom a licence is granted under this ordinance to deposit with the authority a performance bond in an amount to be agreed, but not exceeding [the sum to be stated]. This bond shall certify that all plumbing work performed by the licensee or under his supervision shall be in accordance with the provisions of the code, and that in the case of any violation of any of these provisions he shall pay all fines or penalties properly imposed by the council. A schedule of such fines or penalties accompanies this ordinance.

9. The authority shall have the right to condemn any plumbing materials that do not comply with the standards laid down in the code, and any used material or equipment which the authority deems to be so worn, damaged or defective that its re-use would constitute a sanitary or safety hazard. Such condemned material shall be promptly removed from the site and shall not be re-used for plumbing in the area under the jurisdiction of the authority. It is not the intention of this clause that used material which is capable of satisfactory re-use shall be condemned solely on the grounds that it is not new.

10. The duly delegated representative of the authority (hereinafter referred to as "the inspector") shall have the right of entry into premises for which proposals for the installation of plumbing systems have been submitted to the authority, or in which plumbing has already been installed. Such entry shall be made at a reasonable hour and in the company of a representative of the owner or occupier.

11. Particular premises in which there exists any dual water system, premises in which food, drink or other material susceptible to contamination is prepared, stored or offered for sale, and any other premises which in the opinion of the authority present any special health hazards, shall be periodically examined by the inspector, after a minimum of 24 hours' notice has been given to the owner or occupier, to confirm that the plumbing system is being maintained satisfactorily and in conformity with the code.

12. In the event of any breach of the code the authority shall, within one calendar month of the contravention's being brought to its attention, serve notice upon the offender specifying the nature of the offence and the measures required to remedy it. At the same time, where applicable, it shall draw attention to the statutory penalty laid down for the breach of the code, as listed in the schedule of penalties accompanying and forming part of this ordinance. Payment of the penalty and completion of the specified remedial works shall discharge the offence.

13. In the event that the person receiving notice from the authority disputes the offence in writing within 60 days of receipt of the aforesaid notice the authority may take steps to refer the dispute to a court of law or other form of arbitration to be agreed upon by the parties concerned, both sides to be bound by the decision so reached.

14. The authority may refuse to grant permission for a plumbing installation to be connected to the public water mains or sewers if it has reason to believe that the system contravenes the plumbing code. In such a case the owner or occupier of the premises concerned may call upon the authority to provide details of the alleged infringement of the code. In the event of dispute the matter shall be referred to a court of law or other form of arbitration.

part II

plumbing standards and regulations

7. general observations

Part II of these guidelines covers the standards and regulations that are laid down by the authority by virtue of the power granted by the ordinance. The ordinance and these standards combined, together with any annexes, tables or schedules referred to, constitute the authority's complete plumbing code of practice.

In order to attain a degree of uniformity and to assist the various authorities in the formulation of their respective codes a number of countries have prepared a model series of standards, regulations or bylaws from among which each authority within the country concerned can select and adapt those that meet its particular needs. Several codes of this nature are referred to in the bibliography (Annex 5) and their perusal is recommended to anyone interested in the formulation of national codes or models.

An attempt has been made in these guidelines to give samples of "model" clauses having particular health significance, and to follow each with a discussion as to their purpose and applicability. For clarity the clauses suggested as models have been indented in the text and placed between quotation marks. They have been arranged in a sequence under chapter headings which progress from general to specific conditions but this form of presentation need not necessarily be followed in the compilation of a national code.

> "The following standards and regulations for plumbing systems were prepared under the authority of Clause 3 [page.....] of the plumbing ordinance No .... dated .... and adopted by the town council of ...., being the authority having jurisdiction, at its meeting on ...."

The protection of the health of the people, both that of the occupants of the premises in which a plumbing system is to be installed and that of the public in general, is the underlying justification for the formulation and implementation of each code of practice. The authority may wish to emphasize this point by adding a relevant note of explanation. Another possibility is that the document might be preceded by a set of general principles, such as those listed in Chapter 2.

> "Applications for the authority's approval for plumbing proposals in accordance with Clause 5 [page..] of the plumbing ordinance shall be in such form and shall be accompanied by such plans as the authority shall require."

If the authority requires standard forms to be used for applications, approvals, appeals or other purposes, it can attach to the code a schedule and sample of such forms.

The requirements as to plans accompanying applications should also be clearly defined. If, as discussed in Chapter 5, these requirements may be relaxed in certain cases a note should be added to this effect.

A sample description of plan requirements is given below.

> "Plans accompanying applications for permission to install, extend or alter plumbing systems shall be submitted in duplicate, one copy of which shall be on strong paper or cloth. The second copy shall be returned to the applicant with the authority's formal approval.
>
> "Plans shall consist of elevations and sections as necessary, drawn to a scale of not less than 1:100, showing the following details in relation to all structural features of the building:

"(a) every plumbing fixture, soil-pipe, drain, water service, ventilating pipe, stormwater pipe, grease-trap, interceptor or other apparatus, including the size and gradient of all drains and the diameter of all other piping;

"(b) the height and position of chimneys, windows or other features of the building within a distance of 6 m (20 ft) from the open end of any soil-pipe or ventilating pipe;

"(c) the level of the lowest floor of the building and of the surrounding open spaces, and the relative level of the highway and of the invert of the sewer(s) to which it is proposed to connect the drains.

"A block plan, to a scale of not less than 1:1000, shall also be provided showing the premises at which the work is to be carried out, the limits of the property, the positions of the public water main and sewer(s) at which connexions will be made, and any other relevant details. The premises must be accurately identified by property number or name and street name. The position and diameter of the proposed water service between the main and the premises, as well as the size, gradient and line of any drain, septic tank or other method of waste disposal, must also be shown.

"The plans must include, or be accompanied by, adequate specifications and descriptions of the work proposed. They must be signed by the applicant, who shall state whether he is the owner, occupier or agent of the property. If the applicant is not himself the owner the owner's name and address shall be shown.

"The plans must indicate the intended use of each building covered by the application. Except in the case of single domestic units, the estimated daily consumption of water on which the plumbing design has been based must be clearly shown.

"If it is intended that the water service pipe, drain or any other part of the plumbing system shall cross any land or property that is not under the same ownership as the premises to which the application refers, then the name and address of the owner of such other land or property shall be shown and an indication of the nature of the agreement covering way-leave and right of access for maintenance and repair shall be given.

"The application accompanying the plans shall also give the name and registration number of the licensed plumber who will be responsible for carrying out the work in accordance with the code."

In some cases an application for approval of plumbing proposals may be accepted by the water and sewerage authorities as an application for permission to connect to the main and sewer. In other instances a separate approach is required, and it is worth making the appropriate procedure clear by reference in the code.

"Upon approval of the application the authority shall issue a permit to undertake the work within a stated time, and shall specify the tests to be applied to the plumbing system upon completion."

It is the responsibility of the applicant to ensure that the work is executed in accordance with the plans and specifications submitted with the application, and that any conditions attached to the permit are complied with. As discussed earlier the authority's inspector shall have the right of entry to see that the terms of the permit are being observed.

Upon completion of the plumbing work, but before the ground has been filled in or the internal pipework hidden by structural features, the applicant should give notice that the system is ready for testing. The form of these tests should be decided upon by the authority; in general their purpose is to ensure the watertightness of both water piping and the drainage system.

Normally the water system may be adequately tested by filling the system from the mains and inspecting all joints and fittings for signs of leakage. In complex systems the authority may require an air test, such as one in which the whole of the piping is subjected to a pressure equivalent to 35kPa (250 mm Hg), such pressure to be held for a period of at least 15 minutes. Where such tests are to be performed it is usual for the authority to provide on loan or on hire the necessary compressor and gauges and for the responsible plumber to connect these and set up the test under the direction of the inspector.

Any water used for testing the water piping should be from a potable source, and after completion of the test the authority may require that the system be disinfected. This is normally accomplished by dosing the storage tank with a chlorine compound to produce a 50 mg/litre solution of free chlorine, running all taps and fixtures until the chlorine is evident at all outlets, and allowing the system to stand for at least 12 hours full of the disinfecting solution. It is then flushed to waste until all trace of chlorine has disappeared from the emerging water.

More elaborate disinfecting procedures may be required for complex systems, and for periodic maintenance of piping and storage tanks in buildings serving special purposes - for example, hospitals, boarding-schools, residential hotels, and food establishments. Some suggestions as to these procedures are given in Annex 2. The authority may require a bacteriological test of the water in the system after disinfection has been carried out.

Tests on the drainage part of the plumbing system are usually applied in sections. Underground drains are commonly given a water test as soon as they are completed and the joints are fully set; after approval the ground can then be filled in, thus reducing the time that the site is disrupted. The usual procedure is to insert a drain plug in the manhole nearest to the sewer (this may be at the boundary of the property) and to fill the whole of the subsurface drainage system with water. A head of, say 50 cm (20 in) may be applied by temporarily adding a short length of vertical pipe at the upper end, using puddled clay or other plastic material to form the joint. It is not always practicable to apply this head, especially if there are a number of gullies in the system, in which case the drains will be filled to the highest point possible and the test applied rather more stringently.

The water should remain in the system for a minimum of 15 minutes (1 hour or more if no additional head is applied), during which time the water level should not drop significantly. If the joints of the drain are of cement and are dry the system should be filled at least an hour before the test so that no water is absorbed by the jointing material. If water is scarce, or if for any other reason the authority prefers an air test, the drains should be plugged and subjected to air pressure of 1000 Pa (100 mmH_2O) for a minimum of 15 minutes without a drop in pressure. Excessive pressures of either water or air are undesirable on underground drain-pipes, which are not designed to resist such internal stresses; nor are the joints (especially cement joints of clay pipes) and these may become loosened or damaged if too great a head is applied from within.

As an additional precaution the lower manhole should be inspected after the water test has been completed and the drains emptied, or after a period of rain, to confirm that there is no infiltration from the surrounding ground into the pipe.

Water tests may be applied to the drain outlets from fixtures within the building, but are usually considered too stringent if the building is more than two storeys high. An alternative is a smoke test, in which a machine is used to fill the internal drainage system with smoke under pressure from a testing machine. The vent stack must be plugged at its upper end as soon as the smoke emerges, and the pressure applied should not exceed 250 Pa (25 mm H_2O) or the liquid in the fixture traps will be blown out. The pressure should remain steady for at least 15 minutes, during which time all fixtures, traps and pipe joints should be inspected for signs of emerging smoke.

A simpler, though less effective, test can be applied by introducing a pungent volatile substance into the system, either through the vent stack or by a capsule that will release its contents after passing through a trap. Oil of peppermint, carbon bisulfide, or certain proprietary chemicals are commonly used for this purpose. Evidence of leakage in the system is provided by the presence of odour emitted by the compound inside the building, but it is often extremely difficult to trace the exact point of emergence. This type of test is particularly suitable for maintenance inspections of old systems that might be damaged if pressure were applied.

When the whole system has been successfully tested and inspected the authority should issue a certificate to that effect as evidence that the plumber's work has been properly carried out.

8. capacities and quantities

> "The design of every plumbing system, and the capacity and dimensions of its component parts, shall be adequate to satisfy immediate needs and those that can be reasonably anticipated during its expected life."

To a great extent every plumbing system represents a compromise between what is theoretically desirable and what is practicable. This is especially true in developing communites, or in any poor area, where a rigid insistence on standards applicable under more prosperous conditions might prevent many householders from connecting their dwellings to the public water mains and sewers.

On the other hand, a plumbing system is a long-term investment which should not become outdated and need replacement while it still has a serviceable life. Hence its basic components should be adequate to cater for future needs.

As an example, a town may have a system of water mains but, as yet, no sewerage. Because of this the installation of water-closets is impracticable, and applications may be received for water connexions serving, say, a kitchen sink alone. Theoretically a pipe 10 mm (3/8 inch) in diameter would be sufficient to provide enough water for this fixture, but in the future, when drainage becomes available and demand grows, this size of pipe would be inadequate to serve a water-closet and bath and it would have to be replaced. Since it can be shown that installing a pipe of double the carrying capacity adds only about one-third to the initial cost (laid), it is obviously good practice to make this provision for the future.

> "The design of plumbing systems for various classes of building shall be based on the unit demands listed in Table 1 in the attached schedule."

The authority should decide upon realistic standards for the quantity of water to be supplied in different classes of buildings; the same figure can be taken for the volume of waste to be disposed of in normal circumstances. In each case the actual values will depend on local conditions - for example, whether water is scarce and has to be rigidly conserved, whether household appliances using water are likely to be in general use, whether air conditioning, garden watering and similar uses are anticipated, whether the climate is exceptionally hot, and so on.

As a guide, some sample uses are listed with a range of suggested values within which local demand standards will probably fall.

Table 1
Demand standards for various uses.

Class of building	Consumption per day		
	l	US gal	UK gal
Dwelling houses and apartments, per occupant	40-120	10-30	9-26
Industrial and commercial premises,			
staff sanitary facilities, per staff member	10-30	2.5-7.5	2-6.5
add, per staff member, if showers or baths are provided	10-15	2.5-4	2-3
Hotels, per occupant plus staff:			
with communal baths	100-200	25-50	22-44
with private bathrooms for each bedroom	200-400	50-100	44-88
luxury hotels in the tropics	400-600	100-150	88-130
Hospitals, per bed, including catering and laundry	350-500	90-125	77-110
Nurses homes and medical quarters, per occupant	115-150	30-40	25-33
Schools, per occupant plus staff:			
day schools	15-30	4-7.5	3-6.5
boarding schools	100-200	25-50	22-44
Cinemas, theatres, per seat	8-15	2-4	1.5-3
Restaurants, per seat plus staff	75-100	20-25	16-22
Laundries, per kg dry laundry:			
hand-operated	30-40	7.5-10	6.5-9
mechanized	60-90	15-22	13-20
Airports, bus or railway terminals, per passenger catered for plus staff	15-45	4-11	3-10
add, per passenger catered for, if showers or baths are provided	10-15	2.5-4	2-3

"So far as is practicable each separately occupied building shall have its own service pipe conveying water from the public main. Such service pipe shall be of adequate size to cater for the expected demand, but in no case shall be of less than 15 mm (1/2 in) diameter, and shall be laid below ground with a minimum of..........cm cover. It shall be reasonably level, with no high points where air may become trapped."

If applicable the clause may be extended on the following lines:

"That portion of the service pipe between the public main and the stop tap at the boundary of the property shall be the concern of the water authority, which shall assume responsibility for its future maintenance, the remainder of the service pipe being the responsibility of the owner of the property."

This latter point has been discussed in Chapter 5, and any action taken will depend on the practice adopted by the public supply authority. If this authority supplies and installs the section of service pipe beneath the highway the additional clause will be unnecessary, the stop tap being considered the limit of the public mains system. If this section of service pipe is to be laid by the plumber it may be appropriate to include at this point a summary of the authority's requirements in such matters as the specification of the mains ferrule and the inclusions of a goose-neck or section of flexible piping between the ferrule and the service pipe.

The depth at which the service pipe should be laid will depend on climatic and other circumstances. In areas subject to frost the depth specified should be sufficient to avoid damage from freezing - 1 m (3 ft) or even more may be required. In tropical areas it is desirable that the incoming water should be kept cool, and 50 cm (20 in) may be suitable. Service pipes, especially if made of plastic, are capable of being damaged by cultivation of the ground above them; a depth of 80 cm (30 in) should provide adequate protection. If the owner's part of the service pipe passes under a roadway, boundary wall or other point at which a load might be superimposed on the pipe then special precautions may have to be taken - e.g., increased depth, sleeving or concrete surround, and backfill of selected material, free from large stones and carefully placed.

Only in very exceptional circumstances should a service pipe pass under any building or structure other than the one to which water is to be provided. If this is unavoidable then special precautions should be insisted upon. Under no circumstances whatsoever should a service pipe be permitted to pass through a sewer, manhole or inspection chamber.

> "So far as is practicable each separately occupied building shall have its own drain connexion terminating at the public sewer. Such drains shall be of adequate size, and laid at a constant gradient that will permit their contents to discharge at a self-cleansing velocity. Drains carrying human wastes shall in no case be of a smaller diameter than 100 mm (4 in) for the discharge from a single dwelling, or 150 mm (6 in) if more than one property is served."

Considerations similar to those affecting the previous clause may govern the wording here if the sewerage authority assumes responsibility for that portion of the drain under the public highway.

Since drain construction is limited by more constraints than the laying of water services (e.g., the need to lay pipes in straight lines and at strictly controlled levels) there are likely to be more occasions where a number of plumbing systems have to be catered for by a single connexion to the sewer (Fig. 1). Some authorities insist that cases of this type be covered by a "combined drainage agreement" or other device for ensuring that disputes do not arise over the apportionment of maintenance responsibility. Reference to such requirements may be made in a separate clause in the code.

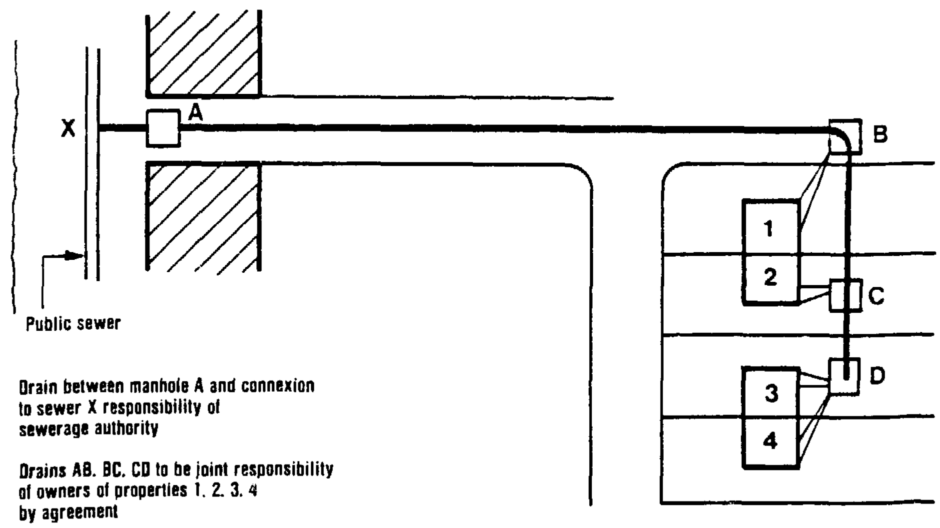


Figure 1.
Situation requiring combined drainage agreement.

Although drains, both within and outside buildings, are often referred to as "horizontal" they should, in fact, never be laid level, but at a constant gradient that will ensure that the contents will flow under gravity even when only a small quantity of sewage is passing. The minimum velocity that will avoid the solids settling and building up to block the pipe may be taken as about 0.6 m (2 ft) per second. This minimum velocity should always be maintained, but there is an upper limit that should not be exceeded because of the danger of scouring and damage to the pipes; 3 m (10 ft) per second may be considered the maximum safe velocity.

Table 2 (which may be included as an annex to the code) shows the gradients at which these velocities are reached in pipes of some of the more common diameters, together with the approximate quantities that will be carried at such velocities.

Table 2
Gradients to produce minimum and maximum velocities in drains.

Diameter of pipe		Minimum velocity 0.6m (2 ft) per second				Maximum velocity 3m (10 ft) per second			
		Gradient	Carrying capacity per second			Gradient	Carrying capacity per second		
mm	in	%	l	US gal	UK gal	%	l	US gal	UK gal
100	4	0.87	5	1.3	1.1	21.7	24	6.4	5.3
150	6	0.51	11	2.8	2.4	12.6	54	14.2	11.8
250	10	0.26	30	7.9	6.6	6.4	150	39.6	33.0
300	12	0.20	43	11.4	9.5	5.0	216	57.0	47.5

If the relative levels of the building and the sewer are such that the appropriate gradient to give a self-cleansing velocity for a particular size of pipe cannot be reached it may be necessary to substitute one of a larger diameter. If the slope of the ground is such that a maximum velocity will be exceeded, the remedy is definitely not to reduce diameter (which would only lead to the blocking of the pipes). Instead, a vertical drop, properly designed in the wall of a manhole, should be used at the upper end of the drain to reduce the gradient in the section.

As with water pipes, drains passing below roadways or other potential loads should be adequately protected from crushing, usually by being surrounded with concrete.

"Table 3 in the attached schedule shows the minimum diameter of water pipes to supply various types of plumbing fixture."

Table 3
Minimum diameter of waterpipes to plumbing fixtures

Fixture	Minimum Diameter	
	mm	in
Drinking-fountain, wash-hand basin, water closet with flush tank	10	$\frac{3}{8}$
Bathtub, domestic dishwasher, hose connexion, domestic water heater, shower, sink, urinal with flush tank	15	$\frac{1}{2}$
Commercial sink, urinal with flush valve	20	$\frac{3}{4}$
Water closet with flush valve	25	1

This tabulation may be reduced or added to according to local circumstances. It is better not to include special equipment (e.g., laundry equipment), but to note that manufacturers' recommendations should be complied with.

9. single dwellings

For the purpose of these guidelines a "single dwelling" is taken to be a house of one storey or more (whether detached or part of a terrace or block), or a self-contained apartment having its own separate water and drainage connexion and no communal plumbing facilities with any other dwelling.

> "The water supply connexion from the water main and the drain connexion to the public sewer shall be laid separately with, whenever possible, a minimum distance of 3 m (10 ft) between them. Where these pipes pass into the building or under any interior wall they shall be adequately protected against stresses caused by settlement or movement of ground."

The quality of materials and workmanship with which these pipes should be constructed are referred to in Chapter 16. It should go without saying that all pipes carrying either water or wastes should be watertight, durable, of smooth and unobstructed interior, and protected against any accidental or other stresses that can be anticipated.

Some authorities permit the water service and the building drain to be laid in the same trench. This is not a desirable practice, since an event such as earth movement or the growth of tree roots may cause both pipes to be ruptured at points adjacent enough to make cross-flow likely. If such a practice is permitted under particular circumstances (e.g. on a very restricted site) the water pipe should be laid on a firm shelf dug along one side of the common trench, it should be at least 50 cm (20 in) above the drain throughout its length, and both pipes should be laid with the minimum number of joints.

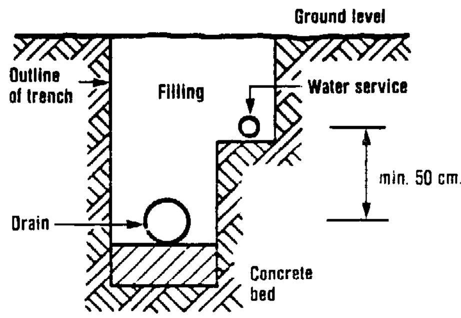


Figure 2.
Common trench for water service and drain pipes: restricted sites only.

Pipes passing under or through walls of buildings should not be rigidly built into the structure, but should be separated by a layer of sand or clay that can take up any stress due to unequal settlement.

> "The water service shall be controlled by an accessible stopvalve, sited as near as possible to the point where the pipe enters the building and before any tappings or junctions are taken from it."

In other words this key control valve should be capable of shutting off the whole of the plumbing system that is under mains pressure. The incoming service within the boundary of the property is further controlled by the water authority's stop valve at the point where the pipe crosses the boundary.

> "Immediately after the stop valve a drain cock shall be so placed as to allow emptying of all internal piping connected to the mains supply."

Although this clause is especially important in areas subject to frost it is a wise precaution everywhere, allowing the water pipes to be emptied if the dwelling is left vacant for a period, and also if it should become necessary to modify or repair any pipe. The drain cock should be easily accessible, and it is useful if it is fitted with a hose connexion to permit the drained water to be led outside the building.

> "In every plumbing system that includes a water-closet or more than two other plumbing fixtures, a storage tank or cistern, controlled by a float or ball valve, shall be provided."

This provision is not insisted upon everywhere; indeed the practice is actively discouraged in some countries because of the danger of the tanks becoming contaminated and forming breeding grounds for harmful organisms. Especially suspect are those sited at ground level (see next clause) and those whose contents can be removed by dipping with a container. Where tanks are not installed it is necessary to permit fixtures to be connected directly to the incoming service pipe, and this undoubtedly saves cost.

There are, however, a number of advantages in requiring each dwelling to have its own storage facilities. In the event of temporary stoppage of mains supply (due to breakdown, repairs or other causes) sufficient water is stored to provide domestic services for a day (or longer in an emergency, if the householders are given due warning). Demand on the mains is smoothed out so that no premises go short during periods of peak draw-off. Pressures on plumbing fixtures remain constant despite fluctuations in mains pressures. (This is especially important where such domestic apparatus as water heaters or washing machines may be used).

But the most significant argument in favour of domestic storage is that it provides an air break that virtually excludes the possibility of back-siphonage and contamination of the public mains. Without this air break it is possible for such contamination to occur whenever the mains pressure is reduced. A flexible shampoo fitting, for instance, left in a basin of soapy water can siphon the whole contents of the basin back into the mains should the pressure be shut off. A garden hose, or a flexible pipe filling a clothes washer, can do the same. Such an eventuality cannot occur, however, when the taps to which these flexible hoses are connected are supplied from a domestic storage tank.

There is one possible objection to a storage tank (apart from the relatively minor expense). If it is left uncovered it may be contaminated by birds or rodents, or become a breeding place for mosquitoes. It should always be covered by a close fitting lid having an overlap to prevent its displacement, but not so airtight that air pressure can build up when the water level fluctuates within the tank. Fig. 3 illustrates a tank suitable for mounting on a flat roof.

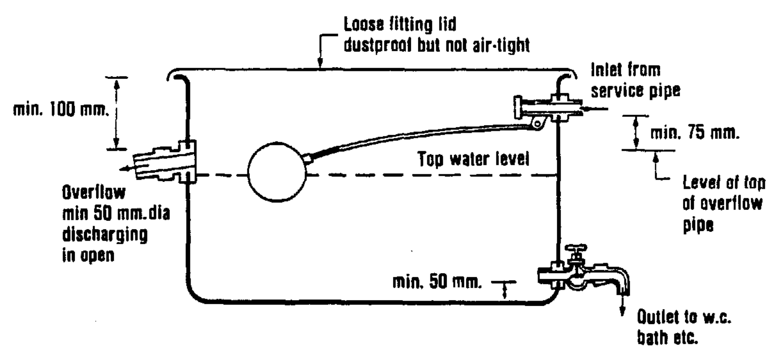


Figure 3.
Domestic water storage tank.

> "The storage tank shall be installed at the highest point of the system, shall be closely covered, and fitted with a telltale overflow and shall be protected against extremes of heat or cold. Its capacity shall be approximately equal to one day's water consumption for the household."

In the case of a house with a pitched roof it is usual to site the tank within the rafters provided that there is sufficient access to permit inspection, cleaning and repairs if necessary. If the dwelling has a flat roof the tank may be mounted on the roof surface. In either case the structure must be strong enough to carry the weight of the full tank (it being remembered that 500 l (130 US gal; 110 UK gal) of water weigh half a ton), and when a larger reserve is desired it may be preferable to distribute the load by interconnecting two or more smaller tanks. A single ball valve may serve to control the level in all of these, but each should have its own overflow.

In a self-contained apartment it may be necessary to mount the tank near to the ceiling - inside an airing cupboard, for example. A drip tray below is often provided to trap any condensation that might collect on the outside of the tank.

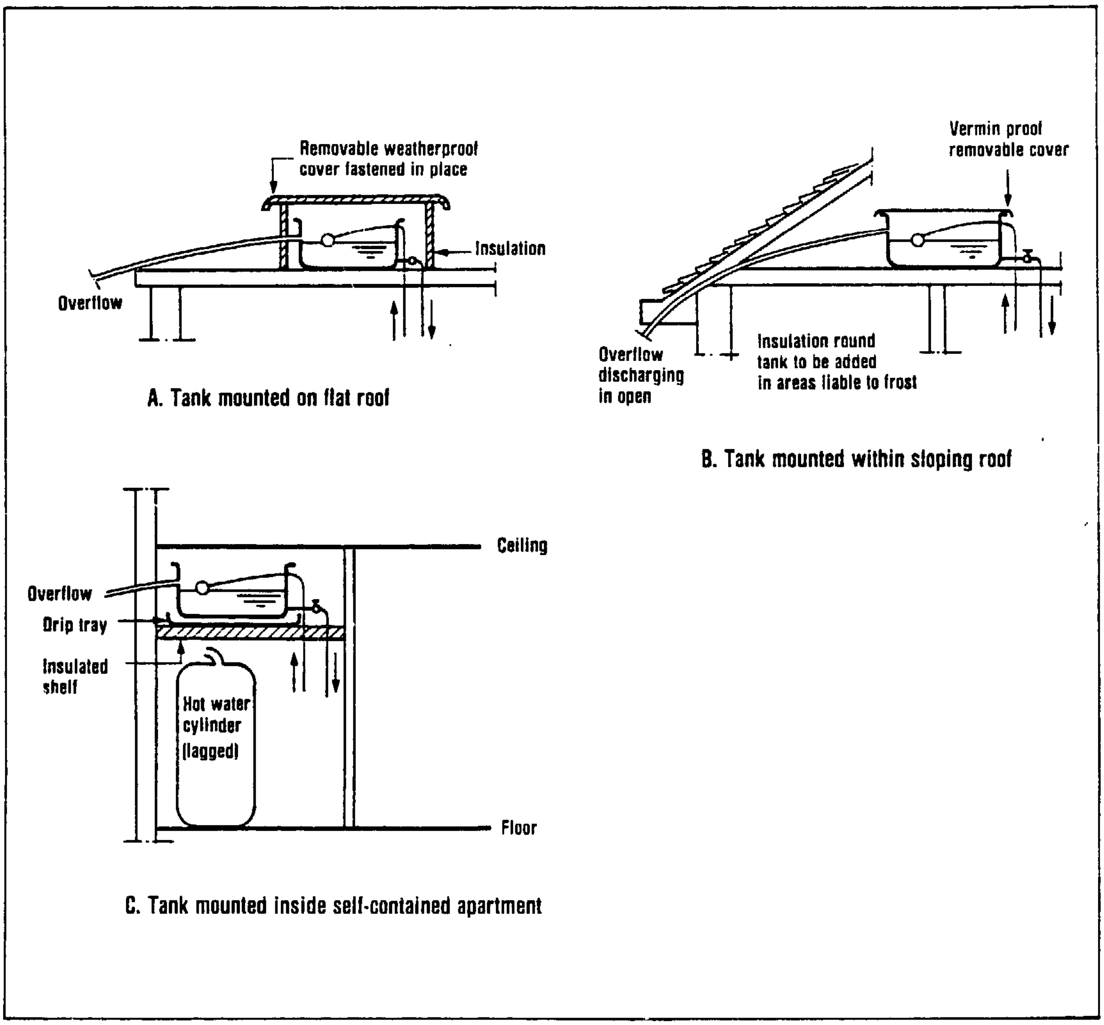


Figure 4.
Water storage tanks.

The authority may specify a standard size of tank, based on the capacity of the dwelling (in terms of number of inhabitants) and the expected consumption per head (see Table 1). Thus, in an area where a daily consumption of 80 l (20 US gal; 18 UK gal) is assumed, a dwelling considered capable of housing 5 people would need a tank with an effective capacity of 400 l (100 US gal; 90 UK gal). An apartment designed for 2 adults and 1 child would require a storage capacity of only 200 l (50 US gal; 45 UK gal).

Where frost is a possibility tanks sited in or on the roof should be adequately insulated against freezing. In hot climates tanks constructed on a flat roof should be similarly protected against undue heating by the sun's rays, and the covering must be weatherproof.

An overflow pipe must be provided in all cases, and this should discharge in the open at a point where it can easily be seen as a warning that the ball valve is not functioning properly. No shutoff valve should be permitted on this overflow pipe, which should normally be at least 50 mm (2 in) in diameter. Sufficient freeboard should be allowed to permit the water to rise to a height of at least twice this diameter above the top of the overflow without spilling, and the ball valve inlet should be not less than 75 mm (3 in) above the top of the overflow, thus providing an air break between the inlet pipe and the water in the tank. In tropical countries the overflow should always be fitted with mosquito screening.

The outlet(s) from the storage tank to the plumbing system should be taken from at least 50 mm (2 in) above the floor of the tank, and should be controlled by a stop valve (or valves) at the first accessible point within the dwelling. Some authorities also insist upon a separate drain, set at the bottom of the tank, controlled by a valve to permit complete emptying of the tank, but in most areas this is felt to be desirable though not absolutely essential.

While tanks should be sufficiently accessible to permit maintenance, cleaning and adjustment of the ball valve, as necessary, they should never be so placed that water can be withdrawn manually by the householder's dipping or ladling.

> "The incoming water service shall be taken directly to the ball valve in the storage tank. Only one connexion may be taken from this incoming pipe, and that shall supply a tap over the kitchen sink."

From the drain cock mentioned earlier the incoming service pipe should be of the same diameter all the way up to the storage tank.

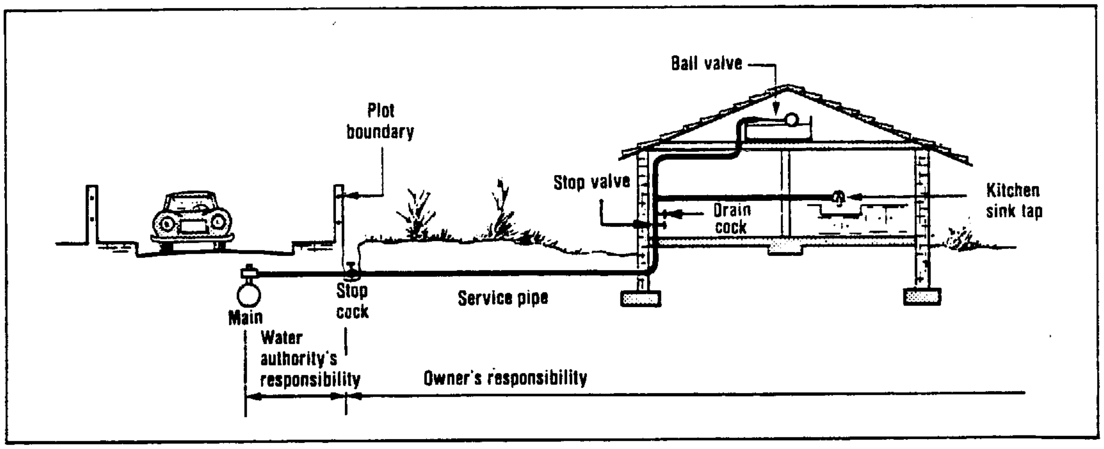


Figure 5.
Water service to a domestic system.

The sink tap connected directly to the main is a double precaution against the possibility of water used for drinking or food preparation becoming contaminated within the building plumbing system. When this connexion is permitted it should be used only for drinking-water and food preparation; no other appliance should be connected directly or by hose to this tap. Some authorities require that the tap shall be of the "loose jumper" type - i.e., the washer assembly is free to move upwards or downwards and is not connected to the hand grip. When the handle is turned to close the tap, the screw action presses the washer on to its seating and the water is cut off. When the handle is turned anticlockwise to open, the washer is not raised by mechanical action but by the pressure of water from below. Hence if negative pressure should occur in the pipe the washer is drawn back on to its seating and backflow is prevented.

> "Connexions from the storage tank outlet to the various plumbing fixtures shall be of the diameters set out in Table 3. (Chapter 8)."

> "Water closets shall each be provided with a flushing cistern, controlled by a ball valve, with separate telltale overflows."

Some authorities permit the use of a "flushometer", or other type of valve, instead of a flushing cistern for domestic water-closets. Less cash saving results than might at first appear, since a pipe of larger diameter is necessary to supply the rush of water required to give a complete flush. Such devices normally use more water than flushing cisterns. Properly designed flushing cisterns deliver a fixed quantity of water in a short period, and refill at a steady rate through a ball valve. They also provide an additional health safeguard through the air break in the cistern.

Overflows, normally at least twice the diameter of the inflow pipe, should be taken through the wall to discharge outside; they should not discharge into the closet pan. They should be sited so as to be easily visible to act as a warning that the ball valve is not operating properly to cut off the incoming supply.

The ball valve inlet itself should be set higher than the top of the overflow pipe, the vertical separation being at least one-and-a-half times the diameter of the overflow; if a silencing pipe if fitted, this should be perforated to prevent back-siphonage.

"Sinks, wash-hand-basins and similar fixtures shall incorporate overflows which shall discharge into the waste pipe below the stopper but above the outlet trap."

"The outlet from every plumbing fixture shall be separately trapped by a water-seal device having a liquid seal of not less than 50 mm (2 in) and not more than 100 mm (4 in) in depth. The pipe leading from the trap shall have a diameter at least equal to that of the trap itself."

The requirement that each plumbing fixture should be equipped with its own separate trap may be relaxed under certain circumstances, notably when "combination" fixtures are used, - i.e., prefabricated units incorporating shower, wash-hand-basin, sink, or other fixtures. It is also sometimes permitted to install separate fixtures of this nature and combine the untrapped outlets into a single trap serving all. Under no circumstances should a water-closet be part of such an arrangement.

Generally speaking, it is better to insist upon individual trapping. The amount of money saved by combining outlets is small, and the drains above the trap are more subject to clogging and the emission of foul odours due to the deposition of grease or soap on the wall of the pipe. Cockroaches and other vermin may also breed in untrapped drains.

The outlet from a water-closet should be not less than 75 mm (3 in) in diameter. Other domestic fixtures should have outlets of at least the following dimensions:

	mm	in
Wash-hand-basin	30	$1\frac{1}{4}$
Bathtub, bidet, dishwasher, sink, shower	40	$1\frac{1}{2}$

Every such fixture should have a grille or strainer to prevent solids, such as pieces of soap, from entering and choking the trap.

> "Water-closets shall be connected to the horizontal drain leaving the building by the shortest practicable route. In the case of dwellings having more than one storey, the drain from a water closet on the upper floor shall descend vertically, the upper part of this vertical pipe being carried upwards to terminate in the open air above roof level. In single-storey buildings a vertical ventilation pipe shall be carried upwards from the top of the drain as close as possible to the outlet from the water-closet."

The vertical ventilation or stack pipe is an essential feature of all plumbing systems. Not only does it prevent foul odours from the drain from entering the building, but by providing an outlet to the open air it ensures that neither vacuum nor pressure can build up in the drainage system that might suck or blow the liquid seal from the fixture traps.

In some countries the most common method of installing the stack pipe in single dwellings is by mounting it outside against the exterior wall of the building. The weight of the pipe is supported at the lower end by a radius bend set into a block of concrete adjacent to the building foundations. Its upper end is taken through or round the eaves (of a sloping roof) and extended upwards at least 30 cm (1 ft). The water-closet is sited inside and adjacent to the exterior wall and its outlet carried through the wall to join the stack pipe at a junction fitting.

Exterior stack pipes of this nature are not used in all countries. In cold climates the danger of blockage or fracture from freezing prevents their use while in some places they are considered as an eyesore, spoiling the appearance of the building. In such instances the authority may require that the stack be installed within a wall where it cannot be seen except for the section which projects through the roof. An interior stack should be tested to ensure that all joints are water tight prior to the application of the wall finishing material which will conceal the piping. This may be done by closing all outlets except the highest and completely filling the piping with water. All joints should be visually examined for leakage after the water has been in the piping for not less than fifteen minutes. If leaks are detected, the water should be drained from the piping, the leak repaired and the system retested until no leaks are evident.

After a system with interior stacks is completed and in use there is a possibility that any leak which develops in a concealed section of piping might go undetected and a foul odour may be the only indication that a pipe is not water tight or gas proof. Exterior stacks eliminate this possibility since there is less chance that a drip from a defective joint will pass unnoticed Furthermore, repair of a leaking joint in an exterior stack is a relatively simple job because the piping is readily accessible.

From the health point of view there is no significant difference between systems built with exterior stacks and those with interior or concealed stacks. When plumbing is to be installed in existing buildings which are not already equipped with plumbing systems, the work of installation may be simpler and less expensive if external stacks are permitted. Choosing between the alternative systems is a responsibility of the authority and this choice should be made in the light of local preferences and local conditions.

The upper end of any stack should be at least 30 cm (1 ft) above roof level. If the roof is flat and accessible this height should be increased to at least 2 m (6 ft). The stack pipe should be well clear of windows or fresh-air inlets, and should be protected by a wire cage to stop birds nesting. In tropical climates it should also be screened against mosquitos.

Where it is impossible to carry any internal stack above roof level it may be taken through the outside wall of the building and carried upwards to terminate at least 3 m (10 ft) horizontally from, or 75 cm (2.5 ft) above, any window or other opening of the building or of any adjacent building.

No vent pipe, either above the roof or through the wall, should be used for any other purpose, such as supporting an aerial, stay wire, or other structural fixture.

The connexion of the water-closet outlet to the stack pipe should be by means of a junction fitting. Where the water-closet pan is set on a rigid floor - e.g, concrete - the pipe connecting it to the stack may be of rigid material with cement mortar or other solid jointing. Where the floor is of wood or other resilient material, either the pipe must be of plastic or of similar nonrigid composition or the joint between the pan and the outlet pipe must be flexible, otherwise there is a danger of the pan snapping.

Where (in a single-storey building) the stack is carried upwards from the top of the water-closet outlet pipe, the weight of the vertical stack must be either supported independently or a concrete base block must be provided to prevent deformation or crushing of the horizontal outlet pipe.

At the bottom of the stack pipe a radius bend (to prevent clogging) leads the water-closet outlet to the head of the horizontal drain connecting with the public sewer. Outside the building at least one watertight inspection chamber or manhole should be constructed; this should have a rigid cover capable of bearing any loads which its situation exposes it to. This manhole serves several purposes:

(1) An access point from which the drains can be inspected and rodded (both toward and away from the building).

(2) A point from which tests can be applied to the drainage element of the plumbing system.

(3) A junction into which the drainage from other plumbing fixtures may be brought to discharge into the horizontal drain. If more than one water-closet is installed in the building the junction between them must also be made in such a manhole.

Wherever there is a change of direction or gradient of the horizontal drain, a junction of two drains, or a length of drain of more than 120 m (400 ft), an additional manhole should be constructed.

> "When the two pipe system with exterior stack pipes is used the outlets from fixtures other than water-closets shall be carried outside the building and discharged into suitable gullies, the outlets from which shall be laid in the same way and of the same materials as the horizontal drain, which they shall join in an inspection chamber or manhole."

Relaxation of this condition is sometimes permitted where, for example, a single wash-hand-basin or similar fixture is to be connected directly to a stack or horizontal section of the drainage system within the building. In such cases a properly made fitting should be used with no interior obstruction that might cause clogging, and any connexion to a horizontal section should be made at the top of the pipe. Cleaning eyes should be provided to enable all parts of the connexion to be rodded.

Sometimes, as shown in Fig. 6(a), the outlets of two or more fixtures such as a shower and wash-hand-basin are combined, though it is preferable for the junction to be made at an outside gully, protected by a suitable curb from rainwater. Upstairs fittings are best dealt with by discharging them to a hopper head (a funnel-shaped metal collector) mounted on a vertical stack pipe attached to the exterior wall of the building. The lower end of this vertical stack discharges by means of a shoe (a short bend of 45 degrees or less) over a ground-level gully.

Special circumstances (e.g., liability to regular periods of hard frost) may make it desirable for all drainage to be kept within the building. In such cases the one-pipe system may be permitted, as described in Chapters 10 and 11. If so a suitable clause should be inserted in the code.

Formerly it was considered necessary for an "interceptor chamber" - i.e., a manhole with a trapped outlet - to be constructed at the last point on the property before the horizontal drain crossed the boundary. Some authorities' regulations still make this a requirement, occasionally a fresh-air inlet is also called for, but modern practice omits this trap in the drain as unnecessary, provided that the plumbing system is ventilated as described above.

> "The drain shall terminate at the public sewer, to which it shall be connected by a branch fitting or by a saddle jointed to the upper part of the pipe."

The sewerage authority will often have its own regulations for jointing to the sewer, and these may be incorporated either into this clause, or into the clause already discussed in Chapter 8 (page 57).

Frequently the actual jointing operation is carried out by the authority's own workmen (the cost being charged to the owner of the building); in some cases the authority will undertake to construct the whole of the drainage from the property boundary to the sewer. Such an arrangement frees the owner from the responsibility of opening the highway, controlling traffic while the trench is open, reinstating the surface and so on. Much will depend on whether the authority takes over ownership and the onus of maintenance of this section of the drain. The [illegible] a good place to define the respective responsibilities of [illegible]ity and owner in this matter.

10. multiple dwellings

As used in these guidelines, the term "multiple dwellings" may be taken to mean domestic buildings housing more than one family. Apartment buildings, tenements, hotels, barracks, nurses' homes and boarding schools may all be included in the description; the common factors are, first, that their prime purpose is for living in and, secondly, that at least part of their plumbing systems are in communal use.

Because they are in dwellings the basic types of fixture will be the same as those dealt with in the previous chapter, i.e. water-closets, baths and showers, sinks and wash-hand-basins. Other fixtures may also be introduced - for example, drinking-fountains, laundry appliances, and urinals. Water is drawn from public mains; wastes are evacuated to sewers; plumbing systems must be watertight and adequately ventilated. Health hazards are similar to those already described, but are intensified by the possibilities of cross-contamination of the water supply of one resident through the carelessness or insanitary behaviour of another. Health precautions must therefore be similar to, but more stringent than, those already described.

Referring back to the first two clauses suggested in Chapter 8:

> "The design of every plumbing system, and the capacity and dimensions of its component parts, shall be adequate to satisfy immediate needs and those that can be reasonably anticipated during its expected life."

> "The design of plumbing systems for various classes of building shall be based on the unit demands listed in Table 1 in the attached schedule."

Whenever water flows in a pipe there will be some resistance to its flow as a result of friction between the flowing water and the walls of the pipe. This resistance is related to the velocity of flow, the roughness of the piping material and to the diameter of the pipe. In single dwellings the resistance to flow in water and drainage pipes will be very small provided that pipes of recommended diameters and materials have been installed. The pipework in multiple dwellings is more complex and resistance to flow must be taken into account when designing the system in order to accommodate the high rates of flow that will occur when several plumbing fixtures are being used simultaneously. In a single dwelling the fact that, say, a bath is being filled at the same time as a water-closet flush tank will result in only a minor slowing down of the respective flows. In a multiple dwelling there is a possibility that a number of different fixtures will be operated simultaneously, and this could have more serious effects - e.g., some fixtures may receive no water at all, or the drainage system may become temporarily overloaded.

The theoretical solution is to design a system of such a capacity that if every fixture were in use simultaneously the water pipes would carry a sufficient quantity to supply the demand and the drainage pipes could cope with the total volume of wastes. Such a plumbing system would be very expensive, and the chances that the situation described would actually arise are so small that the extra cost would not be justified.

Various compromise formulae have been worked out, and are applied in different countries as a basis for the design of multiple dwelling systems. Annex 3 describes two of these. Any authority expecting that a number of multiple dwellings will be erected in its area of jurisdiction may well include one of these design methods in its code of practice. If such an event is likely to be infrequent it may be preferable to insert some such general clause as:

> "Pipe sizes for buildings other than single dwellings shall be designed according to a method approved by the authority, and the calculation sheets shall be submitted with the application."

The size of the water storage tank needed will depend on such factors as the capacity and pressure of the public main supplying the building, the probability of an interruption of main flows, and whether a hot water and central heating system is to be installed. In general the storage requirement of one day's estimated consumption for the building is a useful one, but this is sometimes relaxed by as much as 50% where cost considerations are particularly important.

> "In multiple dwellings having units under separate occupation, control valves shall be inserted into the water supply system to enable each separately occupied unit to be isolated from the remainder of the building."

Not only does this permit repairs or maintenance to be carried out in one dwelling unit without interfering with the supply to other occupants, but it also enables the water to be cut off in a temporarily unoccupied apartment. In such buildings as hotels or boarding-houses, especially where water-closets or bathrooms are used communally by a number of occupants, there may be less necessity for separate control of each dwelling unit, but it is a wise precaution to insist on having sufficient valves to control relatively small groups of fixtures or rooms, thus minimizing interruption of the system as a whole if maintenance is required on any section.

Some authorities go farther and require each fixture to be controlled by a separate valve, thus allowing that fixture to be serviced or replaced without shutting off any other fixture. This is useful as a health precaution in multi-storey buildings, where there is always a potential hazard of negative pressure and back-siphonage whenever a substantial part of the system has to be shut down or emptied.

Drainage from a multiple dwelling may be designed either on the "one-pipe" or on the "two-pipe" principle and the decision as to which system to adopt must be made by the authority. Briefly, in the one-pipe

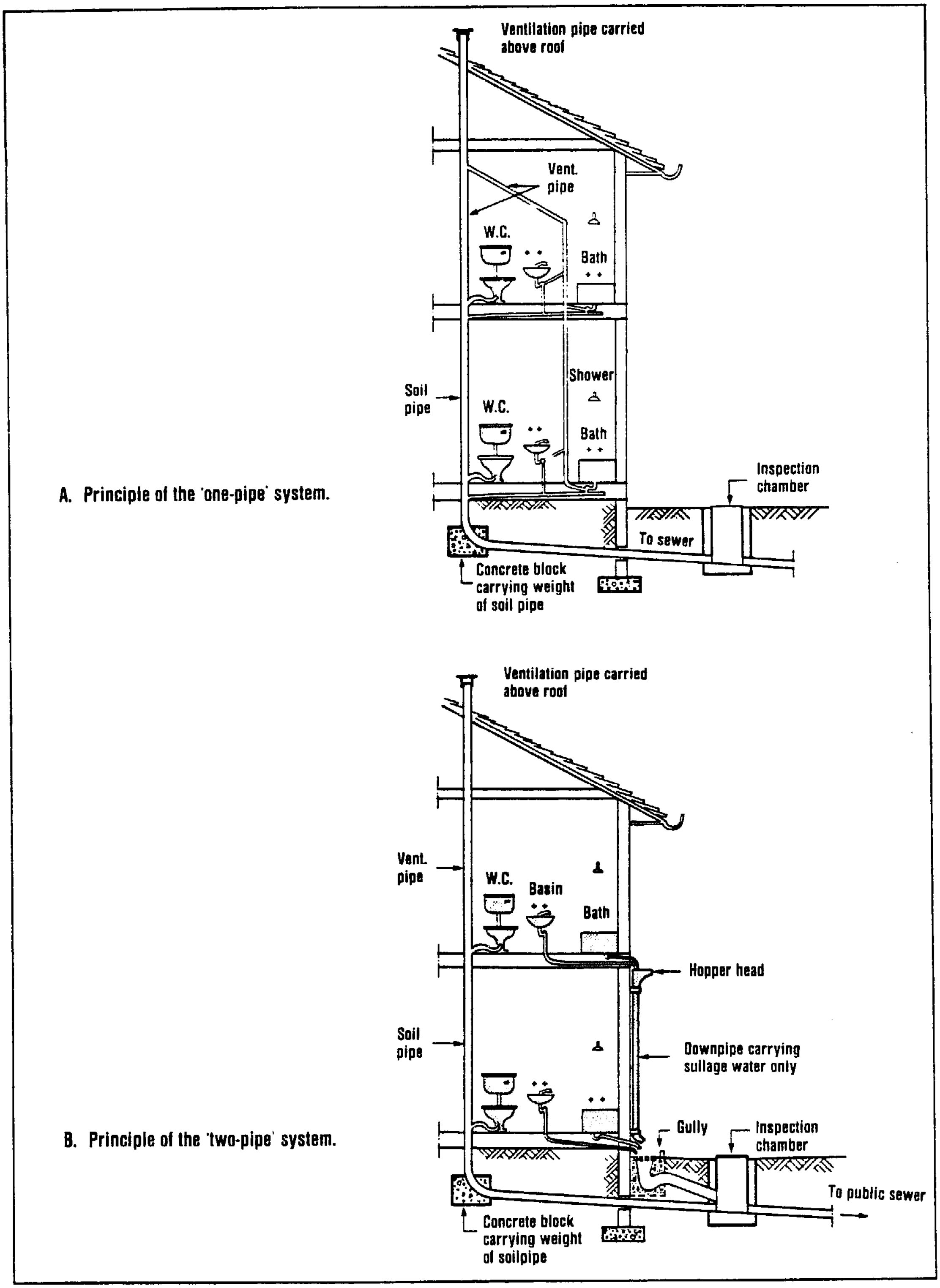


Figure 6.
Building drainage.

system all wastes from water-closets, sinks, baths and other fixtures are collected together and conveyed to the underground drainage pipes by common stacks, all branches being ventilated to protect the traps from positive or negative air pressure. In the two-pipe system the wastes from soil pipes (i.e., those from water-closets or urinals) are collected together in stacks, while wastes consisting of sullage only (i.e., from baths, wash-hand-basins, sinks and the like) are kept separate and discharged outside the building into gullies. Sullage from upper floors is conveyed to the gullies by vertical pipes outside the building open to the air at the top and bottom, the waste pipes from the fixtures being carried through the exterior wall into hopper heads at the upper end of these vertical pipes.

In very large and complex buildings, and in areas where external pipes are undesirable (e.g., because of the congestion of buildings, or because of the risk of frost damage) it may be desirable to allow one-pipe plumbing despite the more elaborate ventilating system that this necessitates.

Further details of the one-pipe system are given in Chapter 11; the next two clauses are applicable where the two-pipe system is adopted.

> "The contents of soil pipes used for the conveyance of human wastes shall be collected into vertical stacks, the lower ends of which shall be connected directly into under-ground drains. Junctions between drains from different stacks shall be made in covered manholes outside the building. Each stack shall be carried separately above the roof to form a vent, unless special conditions make it desirable to combine the upper ends of two or more such stacks into a common ventilating shaft."

Careful planning of the building enables the number of stacks to be kept to the minimum by grouping the water-closets closely together, and one above the other in buildings of several storeys. The length of the outlet pipe between the fixtures and the stack should be kept to a minimum in every case.

Many authorities require that the stack pipe shall be sited outside the building for the reasons given in Chapter 9. In the case of buildings such as hotels, where a large number of rooms have individual water-closets, it would be impracticable to site all these pipes on exterior walls, so a number of "wells" or shafts are often constructed within the building but open to the air at the top. Technically any stack within such a shaft is outside an exterior wall, but unless carefully designed and maintained these shafts themselves may present health hazards. They must be accessible for cleaning, and ventilated at the bottom as well as open at the top to prevent the build-up of gases; they must be drained, since, being open, there is nothing to prevent the entry of rainwater. Should a break or burst joint occur in a soil pipe, it must also be feasible to drain away the resultant sewage outflow.

Shafts of this nature are also favourite runways for rodents and other pests, and only constant surveillance and cleansing can keep them clear of rats and cockroaches. They must always be of sufficient size for repair work to be carried out on pipework, and this signifies that there must be access for both men and lengths of pipe.

> "Fixtures other than those carrying human wastes shall have their trap outlets carried to the open air through an exterior wall, and shall there discharge either directly to a gully, or through a hopper head into a vertical pipe set over a gully, the outlet from which is connected to the underground drain in a manhole. Should the number of fixtures be so large as to make individual discharges of this nature impracticable, the outlets may be combined into suitably sized common outlets, discharging either to the open air as described or into stacks conveying

sullage water only. Where fixture outlets are combined in this way each outlet shall be separately ventilated as a protection against exhaustion of the liquid in the trap seal."

Ventilation may be to the open air by means of "puff pipes" - separate short lengths of pipe 25 mm (1 in) in diameter terminating in a wire grating or mosquito gauze capping outside the exterior wall. Alternatively, the ventilating pipes from the fixture drains close to the downstream side of each trap may be combined and carried upward to a sullage stack at a point above the highest connexion carrying liquid waste to the stack.

11. multistorey buildings

The term "multistorey buildings" is used in these guidelines to refer to buildings that are too high to be supplied throughout by the normal pressure in the public mains.

Since mains pressure fluctuates during the daily cycle of peak and low demands there will be borderline cases of buildings where water will reach the roof tanks only during periods of minimum demand, usually the early hours of the morning. Such "borderline" buildings may be catered for by increasing the roof storage capacity and the diameter of the incoming service connexion so that the day's supply to the building plus the normal reserve storage capacity is drawn during the period when mains pressure is high.

From the water authority's point of view there is some danger in relying on this situation continuing; additional demand in an expanding public water supply system may cut down the number of hours when the pressure is high enough to reach the building's storage tank, so that in the future the authority may be faced with the necessity of making special arrangements to supply higher pressure water. This may not be possible with the existing mains system, or may require the provision of pressure-reducing valves to properties elsewhere. Permission to treat a multistorey building as a borderline case should therefore be granted only after most careful consideration, and it may be necessary to insist that the plumbing should be so designed that it can be easily converted to a true multistorey system in the future.

Water pressures in a typical mains system in a developing country may fluctuate within a range of 8 - 12 m (25 - 40 ft) head, in which case a 2-storey building can be adequately served, but anything higher may need a pressure-boosting system. In hilly areas the pressures will be different in high and low parts of the town, and the water supply authority may have to specify areas where particular pressures can be relied upon.

> "Whenever a building of 3 or more storeys is proposed a certificate from the water supply authority shall be obtained guaranteeing that the mains pressure at the time and in the future will be adequate to reach the storage tank, failing which suitable arrangements for boosting the pressure to serve all the fixtures shall be made."

Pressure-boosting systems are commonly of two types: a pump lifting water from a ground level or basement tank to a roof tank, or a hydropneumatic system that delivers water throughout the building by air pressure. A third method, whereby a booster pump is inserted in the service pipe, drawing directly from the main and delivering to the roof storage, is not recommended. Although cheaper at the outset, it must be controlled by automatic pressure cutout switches, otherwise a negative pressure may be produced in the mains, with the resultant risks of damage and of contamination.

With either of the approved methods the system may be separated to allow the lower two or three floors to be supplied from normal mains pressure, the boosted supplies serving the storeys above.

> "Where booster pumps are installed a covered ground-level tank with a capacity of at least 50% of the daily requirements shall be supplied directly from the mains through a ball or float valve. From this tank the booster pump shall lift directly through a riser pipe to the roof storage of similar capacity. No other connexions shall be taken from the riser pipe. Booster pumps shall be installed in duplicate, each having its own switchgear and protective devices, in the event of breakdown."

In the case of high-rise buildings of over, say, 12 storeys the system should be divided with separate pumps and tanks supplying 5-8 storeys each. Not only does this save pumping costs but it also prevents excessive pressures on the lower fixtures.

From the roof (or intermediate) storage tanks a horizontal loop manifold should be laid around the building from which vertical water downtake pipes are taken to serve the fixtures below. Each of these downtake pipes should be controlled by a valve; if necessary, pressure-reducing valves should also be included to protect the fixtures in the lower storeys. The sizing of the manifold and downtakes should be such that negative pressures cannot occur in any part of the system.

> "Hydropneumatic systems, where installed, shall serve no more than 7 storeys each. Pressure vessels shall be fabricated and certified to withstand the pressures to be encountered with an approved factor of safety. They shall be supplied with water from a covered ground storage tank, holding 50% of the estimated daily requirements by means of at least 2 booster pumps, each with its own switchgear and safety devices, and capable of coping with the estimated peak demand load. The pressure vessel shall have a capacity of at least 3 minutes' peak demand, and duplicate air compressors shall be provided to maintain the designed air/water ratio."

Again, hydropneumatic systems should not be supplied with water pumped directly from the mains. The ground (or basement) level tanks should be totally enclosed and provided with overflows, float valves and warning devices. They must always be sited above the level of the underground drainage system, and no horizontal drain should pass immediately above or alongside any such tank. They should be accessible for cleaning and maintenance, but not to anyone wishing to draw water from them.

> "The drainage system of a multistorey building may be by the one-pipe method. The outlet from each fixture shall be ventilated to a vertical stack pipe, and all stack pipes shall be carried above roof level either singly or in combination."

Common branches to carry the water from a number of fixtures (other than water-closets) to the nearest stack pipe may be permitted provided that they are of adequate capacity and that each fixture outlet is vented, either by a single pipe or by a common venting system.

> "Wherever possible all drainage from the building shall discharge to the public sewer by gravity. Where this is not possible the wastes should be led to a tightly covered and properly ventilated sump outside the building. Sump pumps, together with control gear, shall be provided in duplicate, and the pumping main from these shall discharge into the public sewer at a point, and in a manner, to be approved by the authority."

The most essential feature of a drainage sump is that under no circumstances should the contents be able to flood the basement of the building or - even more important - to contaminate the potable water tank or system, should the pumps break down or the pumping main become choked. The sump should be accessible from outside the building for cleaning, or for emptying by means of a portable pump in a case of emergency.

12. hot water and other dual supply systems

Dual water supply systems are those in which two different grades of water are available in separate piping systems. The simplest and most common example is the provision (as has already been described) of a tap over the kitchen sink supplying water directly from the incoming water service while all other fixtures are fed from a storage tank. Nearly as common is a secondary system of piping carrying hot water to sink, wash-hand-basin and bath. Central heating normally has its own system. Occasionally a water softener is installed to treat part of a domestic system, but apart from these cases dual systems are rarely met with in single dwellings.

In multiple dwelling and multistorey buildings there may be fire protection systems, either of the sprinkler variety or high-pressure mains and hydrants. Industrial and commercial establishments may have one or more systems of piping carrying cooling or process water from a secondary source or mains water that has been specially treated for the purpose.

Whether water in a dual system has been derived from another source or whether it is mains water that has been treated, heated or stored, it is essential that once separated the systems are not allowed to reconnect.

> "No direct connexion shall be made between the potable water supply system drawn from the public mains and any other secondary system of piping. If feed water to a hot water, central heating or other system is required this shall be delivered by discharging over a storage tank through an air break."

Even the directly connected tap over the sink should not be connected back to the piping in other fixture, either through a hose or through a "mixture" tap. This is because it will normally be at a slightly higher pressure than the supply drawn from the storage tank; a connexion would cause water to feed back through the tank outlet, where it would not be controlled by the inlet ball valve. More seriously from the health point of view, if the public main is shut down for any reason the water from the storage tank could be drawn back through the connexion and return to the main.

Since domestic hot water is not normally changed in composition but only in temperature there is no objection to the expansion pipes discharging over the potable water storage tank, from which the feed water to the heater was originally drawn. If, however, the hot water is softened or otherwise chemically changed the expansion pipe should not be returned in this way.

Central heating circulating water is often treated with a corrosion inhibitor or other chemical, and consequently should be completely separated from the potable water. It should have its own feed tank, which may be supplied from the potable water system through a ball valve and air gap. A separate telltale overflow should be provided as for the potable water storage tank.

> "The feed to the domestic hot water system shall be taken separately from the storage tank, controlled by its own accessible valve. If the heating unit is a solid-fuel, gas- or oil-fired boiler the pipework shall be so arranged that the heating unit cannot be emptied while in use, and there shall always be an expansion pipe with a free discharge (which cannot be closed) as a prevention against pressure build-up that might cause the boiler or pipes to burst."

The hot water outlet from a solid-fuel or other type of domestic boiler is usually taken to an insulated hot water storage cylinder - a pressure vessel from which connexions are taken to the fixtures to be supplied. The capacity of the cylinder should be 40 l (10 US gal; 9 UK gal) per person when baths or showers are connected or 25 l (6 US gal; 5 UK gal) per person for domestic uses other than baths.

Hot and cold water piping, especially long parallel feeds supplying fixtures, should be separated by a distance of several centimetres to avoid heat losses, except where the hot water pipes are fitted with insulating covering.

The hot water storage tank may be fitted with an electric immersion heater in addition to, or as an alternative to, being connected to an external boiler. It can also be heated by an immersed coil from a central heating system, in which case there should be no chance of the water from the two systems mixing. Another possibility is an instantaneous gas water heater that may be used for a hot water supply during the summer months, when the use of a solid fuel boiler is undesirable.

Storage cylinders should be made of noncorrosive material, and they, together with attached pipework, heating coils and the like, should all be of a similar metal to prevent electrolysis, which is more likely to cause corrosion in hot water systems than in cold. If steel is used for tank and pipework it should always be heavily galvanized. The insulation of tanks and pipework should be durable and vermin proof.

Hot water systems in which storage cylinders are incorporated should always be fed from a storage tank. If, for any reason, the authority permits the cold water system to be supplied directly from the mains (a practice not generally recommended) a separate feed tank must always be provided for the hot water system. This does not apply to flash heaters or geysers, operated by gas or electricity and supplying a single fixture, provided that nonreturn valves are fitted in addition to the normal safety devices which cut off the gas or current in the event of a fall in water pressures.

Any mixing valves, whether thermostatically or manually operated, such as those serving a shower, a washing machine, or a dual sink tap, should similarly be fitted with nonreturn devices to prevent hot water from entering the cold water system in the event of an interruption of pressure in the latter.

> "Hot water systems larger than those used for single dwellings shall be fitted with protective devices to prevent the build-up of excessive pressure or temperature. Storage cylinders in such systems shall be fitted with drains and with detachable manhole covers to permit regular inspection of the interior."

Buildings such as hospitals, hotels, multiple dwellings and schools require large quantities of water to be heated, stored and distributed. Heating is usually carried out by a separate boiler, by a steam coil, or by a heat exchange from a central heating or other system, and the temperature is normally controlled to within fairly narrow limits, 65 °C (150°F) being an average temperature setting. Thermostatic devices should be installed to cut off the incoming heat source should the water in the storage vessel become excessively hot, and pressure relief valves should also be provided. Both these safety devices should be set in such a way that audible or visible warning is given whenever they come into operation. Heating and storage vessels should be clearly marked with their safe working pressure limits, and gauges should be fitted to enable a regular check to be made that those limits are being observed.

As well as being more subject to corrosion hot water systems are more prone to incrustation from hardness in the water than are cold water systems. In consequence, where large quantities of hot water are used, the hot water feed tank is sometimes dosed with chemicals for softening or for the inhibiting of corrosion. This is an additional argument in favour of strict precautions against the possible subsequent mixing of the waters from the two systems; in addition, care must be taken in the design of chemical dosing apparatus to ensure that water used for solution purposes is supplied through an air break to prevent back-siphonage (Fig. 7).

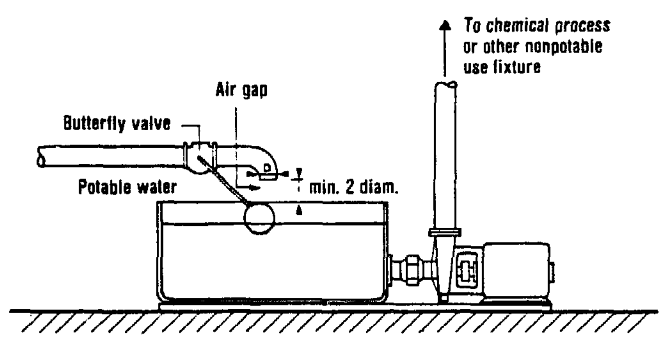


Figure 7.
Air gap protection against cross-connexion.

> "In industrial or commercial buildings, or in any other building having a dual system for fire protection or for any other purpose, cross-connexions between the potable water and any other system shall only be permitted by express sanction of the authority given in writing, and any conditions attached to such sanction must be rigidly adhered to at all times. Specific application in writing must be made for each cross-connexion."

Cross-connexions between pipes containing water drawn direct from the mains and those containing water from another source (or water contaminated by wastes or chemicals) have repeatedly been shown to be responsible for mains contamination. Fig. 8 shows the principle

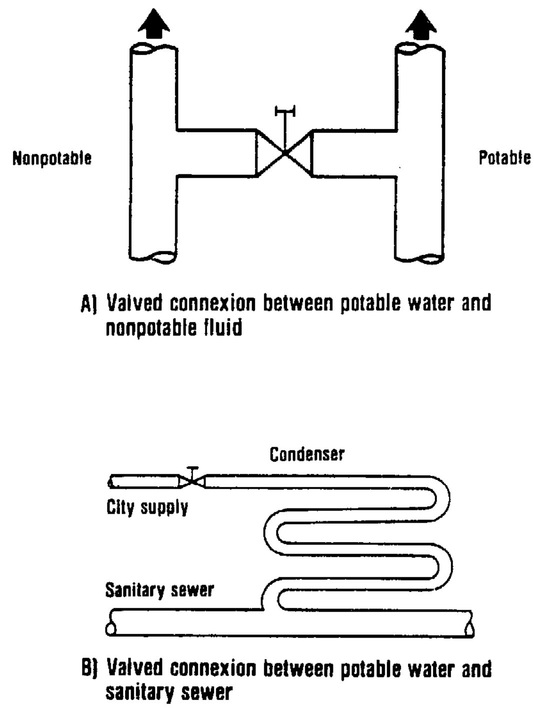


Figure 8.
Elements of a cross-connexion.

involved. In general they should be rigidly banned; the simple process of requiring every plumbing system to be supplied from a storage tank fed through an air break (as described earlier) is sufficient safeguard for the public mains, though still leaving the possibility of contamination within the building (see Fig. 9a. Figs. 9b and 9c illustrate other possible ways of backsiphonage). To insist on this precaution in every new system is well worth while; initial disregard may make it very difficult to adapt the system later should the need become apparent in the future.

There may be some special cases in which mains water under pressure is essential for a particular purpose. In the home, one such special case is the use of a haemodialyser (an artificial kidney), but normally it is in hospitals and laboratories and for certain industrial processes and fire-fighting apparatus that permission will be sought for dual systems.

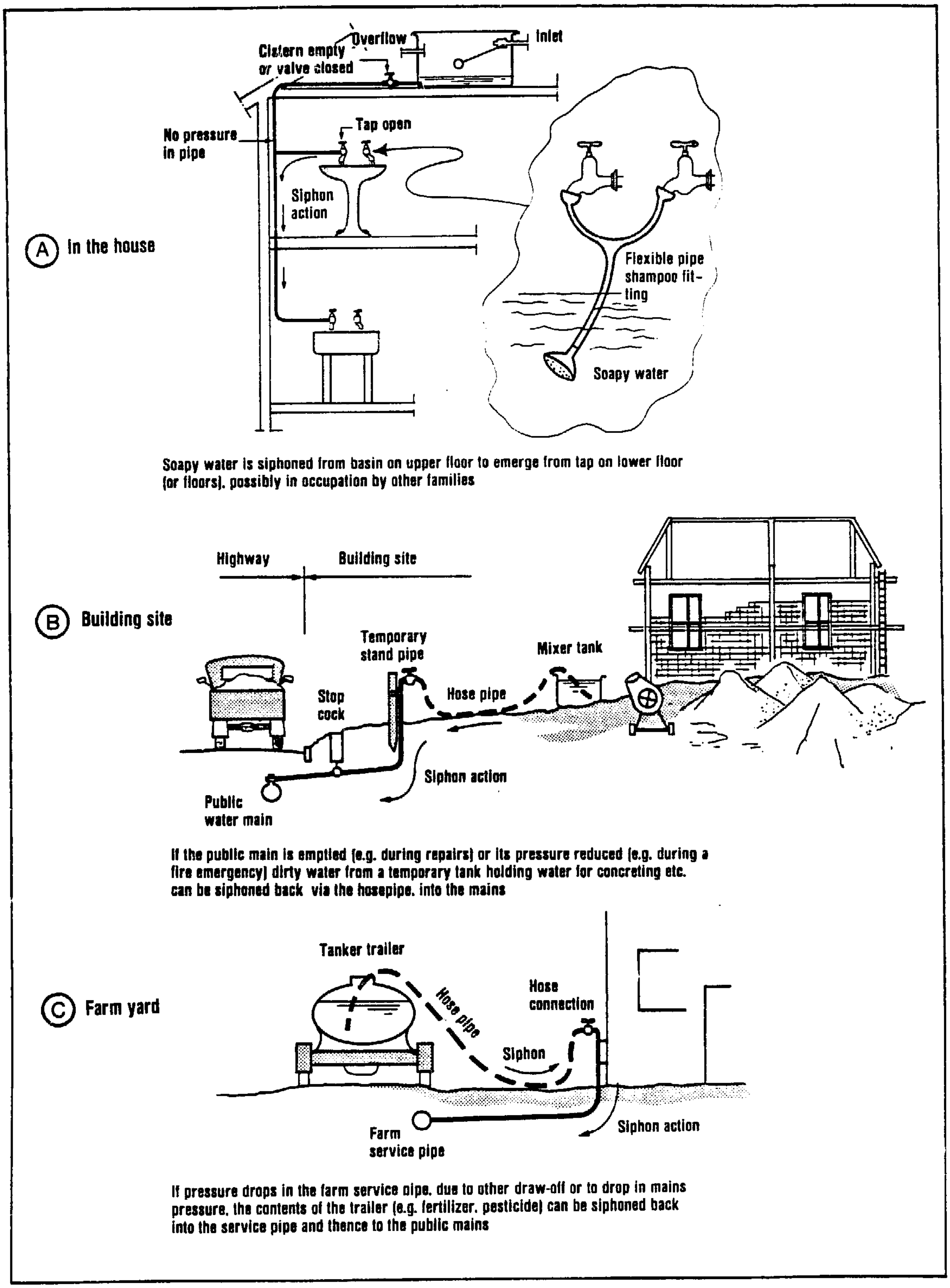


Figure 9.
Ways in which back siphonage can occur.

Sanction should not be unreasonably withheld, since this may lead to clandestine piping that might be very difficult to detect, but whenever a cross-connexion between systems is authorized precautions should be specified and periodic inspection should be made to ensure that these are being maintained. Essentially the problem is to permit the flow of water as required from the system containing pure water to the unsafe one, and to prevent any return flow in the opposite direction. A single valve, whether manually operated or of the "check" variety, is not enough to ensure this.

Two particular devices have been shown to be effective in preventing backflow in a cross-connexion (Fig. 10). The first is an assembly of two check valves and two gate valves; the second is known as a "zone" or "reduced pressure" backflow preventer. The first can be made up by a plumber from standard parts, while the second is factory-made as a single unit. Both should be tested once a year and inspected at regular intervals between tests. The zone backflow preventer has the advantage that in the event of failure to function, water comes from the relief port and acts as a warning.

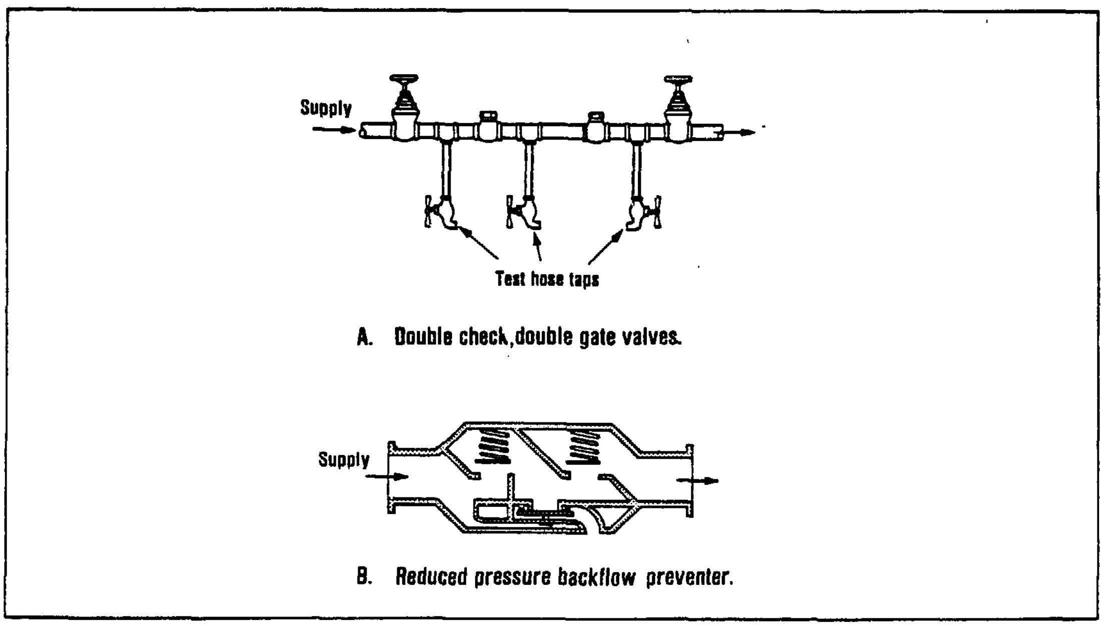


Figure 10.
Backflow prevention devices.

"Whenever dual systems exist, or liquids other than water are conveyed by pipework in a building, the pipes conveying nonpotable water or other substances shall be clearly distinguished by colour or by some other means of identification and precautions taken against accidental use for drinking purposes."

A common requirement is for exposed pipework within a building, and either side of any wall or floor through which the pipe passes, to be marked with bands of colour 150 mm (6 in) wide spaced not more than 7.5 m (25 ft) apart. Various countries have adopted different colour codes, and it is important that the distinction between potable and non-potable water pipes should be standardized nationally and made generally known (see ISO recommendation ISO/R 508-1966). The actual colouring can then be referred to in the code. In addition to the distinguishing coloration of the pipes, identification tags should be fixed to each outlet of nonpotable water. Furthermore signs should be mounted near any nonpotable outlet that might be accidentally used for human consumption. In premises where there are children, all the taps belonging to the nonpotable system should be out of their reach and, if necessary, operated by a detachable key, to obviate any temptation on their part to drink the nonpotable water.

13. stormwater drainage

There are still some sewerage authorities that operate a system of "combined" sewers, to which both sewage and rainwater may be admitted. This practice is not a good one; it is uneconomic in that much greater flows must be provided for, both in the sewers themselves and in the disposal plant, and hazardous to health in that storm overflows have to be provided to cope with heavy downpours. Such overflows are necessary to relieve surcharge of the system at peak flows, and they permit untreated (though admittedly diluted) wastes to discharge into open watercourses.

Combined sewers are rarely installed nowadays, but they are often met with in congested areas of older cities where physical and financial constraints may prevent the laying of a second system of pipes to carry off rainwater.

Where such combined sewers exist the following clauses are inapplicable, but it is strongly recommended that the authorities concerned should consider providing separate sewerage facilities for any new development, since every additional connexion to a combined sewer makes its ultimate replacement more difficult.

Leaving aside this special case, there are three principal ways of disposing of rainwater from roofs, courtyards and paved areas: through a system of stormwater sewers, by soakaways and (from roofs particularly) collection in storage tanks. Stormwater sewers (which may in some cases consist of open channels, lined or unlined) are more common in urban or densely built-up areas, and they normally serve to take the drainage from highways as well as from buildings.

> "Where a stormwater pipe or ditch exists within reasonable distance of the property on which the building has been (or is to be) erected the drainage from the roof and from any paved or

enclosed areas shall be collected and discharged into it in a manner to be approved by the authority."

Frequently the ditches or channels are laid alongside the road just outside the boundary of the property, and are the responsibility of the highway authority, which may well have its own requirements as to connexions. Such requirements should be incorporated into the code. In the case of piped sewers, any connecting drains will need to comply with similar, but modified, criteria to those applying to drains carrying wastes to the soil sewer. The saddle or junction connexion must be made under the direction of a licensed plumber and must not obstruct the flow of the sewer or the drain. The drain itself must be laid to a self-cleansing gradient and must be properly jointed to prevent the access of tree roots or of the surrounding soil, though the materials may not need to be of so high a quality and the drain may not need to undergo a test for watertightness.

Discharges into an open drainage channel may be through a (similarly constructed) pipe or through a subsidiary channel. The usual requirements will here involve the prevention of erosion and of damage to the channel lining. Subsidiary channels and pipes will usually be required to discharge in the direction of flow of the main channel at a level above that of the normal drainage flow. If the main channel is unlined and the discharge into it is through a pipe, a protective concrete apron may be required at the point of discharge. Subsidiary channels should be laid to a self-cleansing gradient, but this, together with their cross-section, may be modified according to soil conditions.

"Discharges into stormwater sewers or channels shall not contain any human waste, sullage water, or other substances that may cause a nuisance or be injurious to health."

In tropical countries having a long dry season small discharges, such as a drain from a single tap, may exacerbate the risk of filariasis, of which the vector breeds in shallow pools or waterlogged ground. Under conditions where a channel or drain may remain virtually dry for perhaps months at a time small discharges may cause considerable nuisance, especially if they contain deleterious matter such as oil or grease. The authority may make special provisions to avoid this - for example, by insisting that a paved area where cars might be washed should be provided with a grease trap.

The dangers must be balanced against the desirability of dealing with clean water discharges without insisting on their being connected to soil sewers. Such instances as the drainage from air conditioning units and of cooling water from a dairy or small industry, or the hosing down of a warehouse floor, should not call for disposal treatment, but the volume of water may be too great to be dealt with by soakaways.

> "Rainwater from sloping roofs shall be collected in gutters and carried to ground level by downspouts. Flat roofs shall be drained through vertical pipes, the drainage being conveyed by pipe to a surface water sewer or to a suitable soakaway."

Except where a roof is thatched, gutters and downspouts should always be considered essential; one reason is to prevent roof run-off falling from a height in concentrated sheets or streams, which would cause erosion close to the foundations of the building. If circumstances render it impracticable to install guttering (e.g., where a roof is old and irregular) a concrete path or apron should be laid immediately under the eaves, and should be so sloped or drained as to carry the water away from the foundations.

The sizes of the gutters and downspouts will depend on the area of roof to be drained, the slope (of the gutter) and the intensity of rainfall to be expected. To insist on guttering capable of dealing with the worst storms would be unreasonably expensive in many areas, and would be of little benefit when the whole of the surrounding ground was being subjected to a downpour. The authority should calculate the storm intensity to be catered for and fix their standards accordingly. Annex 4 gives a table linking roof area, guttering slope and storm intensity; such a table could be adapted to suit local conditions. The capacity of a range of stormwater drains is also shown, and may be applied to the drains connecting the lower ends of the downspouts with the surface water sewer.

Whether or not soakaways are practicable will depend to a great extent on the nature of the soil. They should be well clear of the building foundations, and should consist of holes deep enough to penetrate the subsoil, filled almost to the surface with hard material such as broken stone, concrete or brick that will not soften when wet. Under some conditions, particularly where the water-table is high, it may be preferable to use shallow ditches filled with hard rubble instead of soakaway pits.

> "Where rainwater is to be stored for domestic use the tanks shall be of watertight construction, covered with weather-, insect-, and vermin-proof material, ventilated, and with suitable access for regular inspection and cleaning."

Rainwater storage tanks are a valuable supplement (or even substitute) for mains supplies in arid areas. Their initial cost is, however, somewhat high, since the walls and floor (usually of concrete construction) must be watertight, a system of gutters and collector piping must also be watertight, and the contents must be protected against pollution by dust and refuse blown by the wind, animal ingress and mosquito breeding.

If the rainwater is to be supplementary to a public supply (as a water conservation measure) it may be lifted from the principal storage tank (usually underground or at ground level) by hand pump to a small subsidiary roof tank, often a 200 l (55 US gal; 45 UK gal) oil drum, from whence it is piped to all fixtures except the kitchen sink, which is fed from the public supply. If there is no public main then water for all purposes will need to be taken from the rainwater storage tank. Strict precautions should be observed in such cases to maintain the quality of the stored water. A washout tap should be included in the collector pipe so that the first washings of the roof at the beginning of the rains (these washings will be contaminated with bird droppings, windblown dust, etc.) can be run to waste. It is at this time that the storage tank should be given its annual cleaning, a process that is much easier if the tank is built in two sections that can be emptied and cleaned in turn.

Where rainwater tanks are used it is unlikely that water-closets will be installed; instead some form of pit privy or chemical closet is usual, in which case the rainwater tank must be sited as far as possible from the point of excreta disposal.

part III

special conditions

14. industrial and other special purposes

The bulk of the water supplied through most public systems is used for domestic purposes. Whenever industry and agriculture need large quantities for various purposes it is usually found cheaper for them to install their own supplies or to make special arrangements for their demands to be met from outside. Partly this is due to the economies of bulk use, but a more important factor is usually the quality requirements of the consumers. An industry using large quantities of cooling water, for example, does not necessarily need this to be of potable quality such as is supplied through the public system, but in other instances (e.g., brewing) the quality of water used in the process needs to be even more strictly controlled than that of the public supply in certain respects - for instance, the degree of hardness.

Private supplies of this nature only concern the authority when there is a possibility of cross-connexion with the public supply, or when there are dangers of an unsafe source being used for human consumption. Certain situations encourage both these hazards; in a steelworks, for instance, cooling water from a river or other impure sources may be available in many outlets. Working conditions make the operators thirsty and they need drinking fountains or other potable water facilities, which are normally fed from the public mains. When these facilities are being installed or altered there is a danger of their being accidentally connected to the cooling rather than the potable piping, whereas if they are not provided in sufficient numbers workers are liable to drink from the more convenient cooling water outlets.

Apart from industry there are other sectors in which water use can give rise to hazards. The following are some random examples:

(1) Agriculture - Cattle watering troughs, milk coolers, mixing of chemicals for spraying, filling and cleaning of tankers and other vehicles.

(2) Hospitals - Cleaning of mortuaries and dissecting rooms, washing of research laboratory apparatus, bedpan sluices.

(3) Commercial - Abbatoir cleaning and cooling, market cleansing, car washing, laundries.

(4) Miscellaneous - Fire fighting, sewer cleaning, supplies to ships or aircraft, swimming-pools, automatic drink vending machines.

In all cases there is a danger associated with hose connexions, already discussed, that is the more insidious because precautions against contamination depend on the user rather than the installer and consequently are much more difficult to control.

Authorities preparing plumbing codes should obviously consider carefully the types of uses to be expected in their areas, together with any special hazards associated with these, to enable them to frame their codes comprehensively but without overloading them with inappropriate material. It is often better to restrict the code to basic principles rather than attempt to cover every possible situation in detail, reserving always the right of the authority to impose conditions in special circumstances.

In theory the few fundamental rules are simple and applicable to all types of use - only the practical details of implementation vary according to circumstances. These rules have already been discussed under various headings but may be summed up as follows:

1. Wherever possible, separate water storage should be provided for each building or group of premises serving a common purpose, such storage to be isolated from the mains feeding it by adequate air breaks. (Fig. 11).

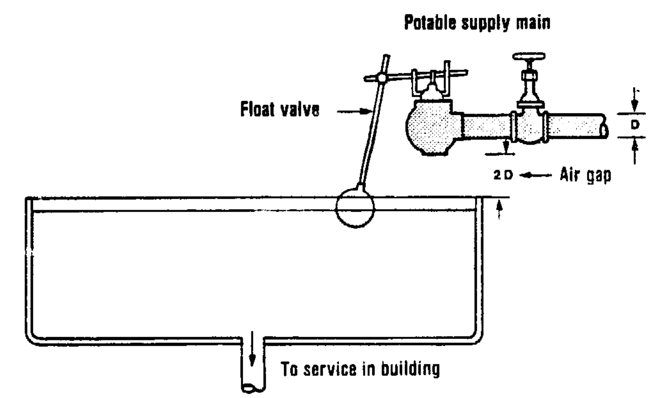


Figure 11.
Storage tank with air gap separation from mains.

2. The only exception should be where mains water is required on the premises for direct or indirect human consumption.

3. No connexion may be made between a pipe containing mains water and any other pipe except by special permission and the installation of approved backflow prevention devices.

4. Any connexion between the piping delivering stored water and any fixture that might contain human wastes, noxious chemicals or other deleterious substances should be protected against back-siphonage by an air break or by some other antivacuum device.

5. Hoses and other flexible piping may only be used for the purposes, and under the conditions, stipulated by the authority. Wherever practicable any tap or outlet intended as a hose connexion should be protected against backflow by a nonreturn valve or similar device.

In some ways the control of the drainage part of the plumbing system may be more difficult than the water supply. It is relatively simple to state the theoretical requirements:

1. All wastes must be removed from the premises as rapidly as possible.

2. Rainwater, floodwater, and uncontaminated process water (such as spent cooling water), should be kept out of public soil sewers and discharged either to surface water sewers or to suitable watercourses.

3. All human and domestic wastes must be kept out of surface water sewers and watercourses, and must be discharged to public soil sewers where these are available.

4. Nothing that could damage, choke or clog the pipes, produce a flammable or explosive mixture, constitute a danger to the public or to the authority's workers, or interfere with the process of sewage purification should be admitted to the public sewer.

Unfortunately, these requirements are often found to be incompatible in industrial and similar premises. For example, rainwater falling on roads and paved areas should be separated from sewage to prevent overloading of the sewage system. It should be discharged to a ditch or watercourse, but if chemical, oil or other spillage on the road is washed into the watercourse serious damage to fish life may result.

Again, waters containing deleterious substances are the inevitable accompaniment of certain industrial processes. These must not be discharged into watercourses or surface water drains. Only two alternatives remain: they must either be taken to the public sewer or must be treated on site to remove the offensive pollutant. The sewerage authority, when coming to a decision as to whether to accept an industrial waste of this nature, will be influenced by various factors. What is the relation between the quantity of effluent to be discharged and the quantity of sewage with which it will be mixed? If the effluent is diluted sufficiently it may be less harmful. How complex is the process of treatment, and what space and facilities are available at the factory site? Treatment may not be a practicable proposition. Are there other industries in the neighbourhood producing similar wastes? There may be arguments in favour of combining the outflows and treating them together.

Some authorities base their charges for receiving and disposing of industrial wastes on the quantity and on the degree of treatment necessary. This encourages larger factories to install their own treatment plants, the cost of which may be offset by reduced sewerage charges, but smaller premises may be unable to do this because of lack of space or of capital. In areas where a particular industry is predominant it may be better for the authority to accept wastes and charge accordingly; a classic instance of such an approach may be seen in towns specializing in the wool trade. Lanolin (fat from sheep's wool) is produced in many of the processes but causes no nuisance while the effluent liquid is hot. By the time it has travelled through the sewers to the disposal works it has congealed, and if not removed would clog the pipes and machinery. Fortunately lanolin is easily separated at this stage, and can even be sold at a profit, but it would be virtually impossible for each individual small factory to construct and operate the cooling tanks and skimming mechanism to remove the lanolin before discharge to the sewer.

When dealing with commercial wastes the authority will also have to be guided by the nature, quantity and strength of the effluent before deciding whether to receive this untreated into the public sewers. Certain premises (e.g., abattoirs, breweries, and dairies) may at particular times discharge quantities of highly oxidizable waste which can upset the biological process at the disposal works unless special precautions are taken. Under certain circumstances it may be necessary to insist on the waste being diverted to a holding tank and released at a steady rate over 24 hours rather than in sudden rushes.

Traps to remove oil and petrol are relatively simple and inexpensive to install and should be compulsory in all commercial garages, car washes and similar establishments, whether the drainage is taken to a sewer or a watercourse. Such traps must be regularly inspected and cleaned or they can actually make matters worse by accumulating oil over a period and releasing it in a single slug when a sudden flush of water reaches the trap. In a similar manner grease-traps (Fig. 12) should be fitted to the outlets from commercial kitchens in hotels, restaurants, hospitals, schools and the like, and should be periodically inspected and serviced.

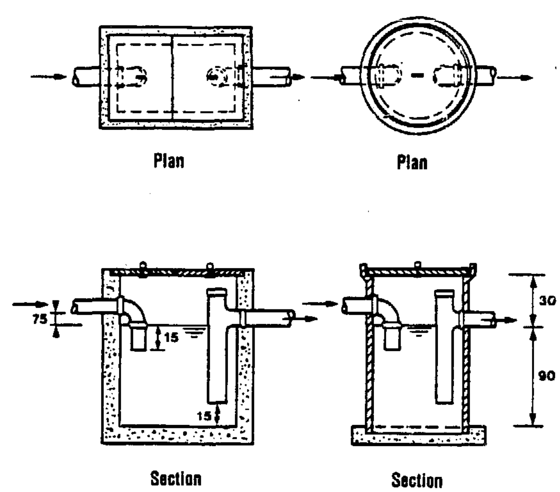


Figure 12.
Typical grease traps.

Apart from these more or less standard precautions the authority may have cause to require particular action in specific cases. Very hot effluents may need cooling before entering the sewers, pH correction may be necessary for very acid or alkaline liquors, trade wastes containing large quantities of solid matter may need screening to protect the sewers from clogging. Each case needs to be considered on its own merits, and the onus of providing estimates of quantities, strengths, temperatures and other characteristics of drainage liquid should be on the applicant. The authority should specify any precautionary conditions based on these initial estimates, but should periodically revise these specifications in the light of inspection and (if necessary) analysis of the effluents actually discharged to the sewer or to a watercourse.

15. protective devices

Vacuum breakers

Devices, including backflow preventers, to prevent cross-connexions from polluting the mains supply have already been discussed. These, if properly installed and maintained, will protect the public mains system, but additional precautions need to be taken to prevent the pollution of the potable supply within a building. The dangers are particularly prevalent in premises serving the public, such as hospitals, hotels and restaurants, but are also present in commercial and industrial establishments in which sanitary and cooking facilities for the staff exist side by side with process and cooling water systems.

The principal cause of backflow is easily defined. Whenever there is excessive or simultaneous draw-off from a number of points in a plumbing system pressure is reduced elsewhere in the system. Where a building is several storeys high and the draw-off takes place at ground-floor level the water in the pipes above may actually flow backwards towards the point of lowest pressure. With many fixtures this results in slight inconvenience only - e.g., the effect at a wash-hand-basin would be that anyone turning on the tap would have to wait for a time before water started to emerge.

There are certain fixtures, however, where a continual draw-off takes place, one of the most common of these being an automatic flush tank for a urinal. A sterilizer in a hospital, distillation apparatus in a laboratory, and a constant-level tea urn in a canteen are other examples. Provided that the fixture is supplied through an air break there can be no trouble other than a temporary interruption of flow, but if the incoming water enters the fixture below its maximum water level a reversal of pressure can suck the contents back into the plumbing system.

A vacuum breaker (Fig. 13a and 13b) is a device to prevent this. Its function is to allow air to enter the pipe as soon as pressure drops, thus preventing any siphon action. It is normally only installed where an air break is not practicable, since the latter precaution is a cheaper and more reliable means of prevention.

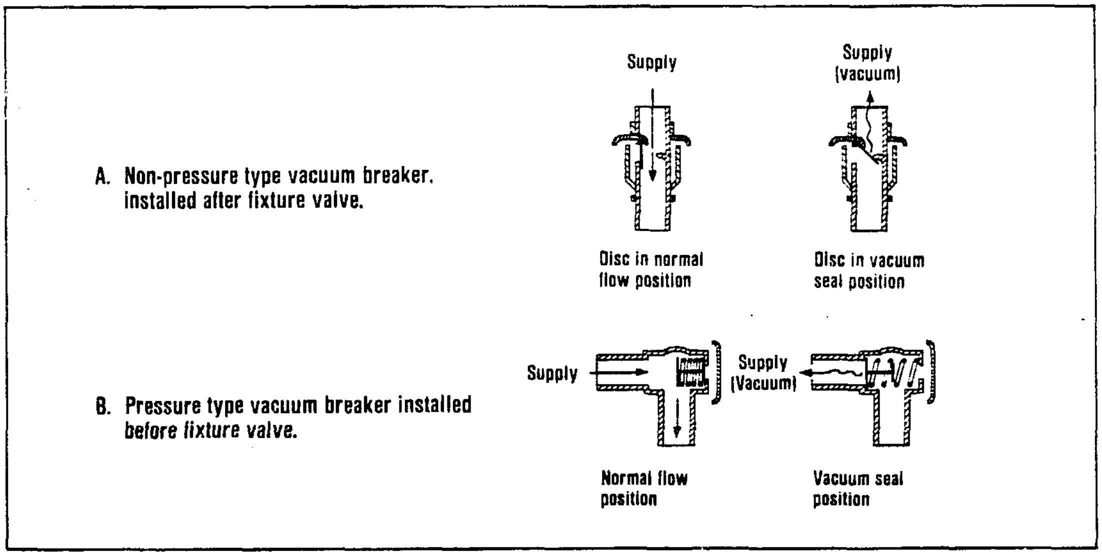


Figure 13.
Vacuum breakers for protecting the supply to plumbing fixtures.

On a small scale back-siphonage may occur when a silencing tube is fitted to a ball valve - i.e.., when the air break is by-passed to avoid the noise of feedwater entering the storage or flushing tank. Provided that the tube is perforated to allow air to enter in the event of reverse flow the device is safe, the perforations acting, in effect, as a vacuum breaker.

Pressure-reducing and nonreturn valves

In certain special circumstances the water authority may insist that pressure-reducing or non-return valves should be fitted to the service pipe supplying water to a building. An example of such a circumstance would be one in which a building draws its water from a pumping main that delivers intermittently to the public systen. Normally no building connexions should be permitted from such a pumping main, but occasionally it is the only way of providing a connexion without going to great expense.

The pressure-reducing valve protects the plumbing system of the building from extreme pressure variations, including surge when the pumps are started and stopped. The nonreturn valve prevents backflow into the main should a negative pressure develop. Neither device is completely reliable, and they should be regarded as a second line of defence - the first being a plumbing system designed (on the lines discussed earlier) so that backflow cannot occur.

Interceptor traps

Whereas a fixture trap is designed in such a way that a smooth flow is maintained and all solids carried by the water pass into the drainage system without interruption, an interceptor trap is designed for the opposite purpose - i.e., to hold back solids and deleterious substances and prevent them from entering the sewer.

At the smallest end of the scale, the gully into which the domestic sink discharges is an example of an interceptor. It is fitted with a grating cover that prevents such items as vegetable peelings from entering the drain, and below this grating is a bowl into which heavy solids may settle, to be cleaned out periodically

Larger gullies, often designed for the exclusion of specific substances, are used for single disposal points in industrial or commercial systems. For example, a yard or highway gully will trap sand, broken glass or other heavy substances that might settle in the sewer; a laundry gully is fitted with a wire basket for catching lint and cloth fragments that might otherwise accumulate and choke pipes. Other types of purpose-made gullies are applicable to particular uses.

For larger industries, or for more specific hazards, it may be necessary to construct interceptor chambers into which one or more drainage outlets are taken before being connected to the sewer. Grease interceptors from commercial kitchens and oil separators from garage wastes are examples. Normally a chamber is constructed below the gradient of the underground drain, the inlet and outlet entering at about half its depth so that neither floating nor settled matter can escape through the drain. The chamber must be well ventilated: preferably it should be covered only with loose slabs or boards so that it is easy to clean as well as being self-ventilated. Another common use of an interceptor chamber is in an abattoir to prevent entrails and offal from entering the sewer.

Interceptors, whether of the gully type or specially constructed chambers, must always be accessible for regular inspection and cleaning. Whenever possible they should be sited outside the building, otherwise they must be proof against overflow and ventilated to the outside air. An interceptor that is not regularly cleaned and maintained may present a worse hazard than the lack of one.

Backwater preventors

A backwater valve is a device for preventing sewage or drainage water from flowing back into a building in the event of flood or sewer blockage. It is usually fitted to a gully in a basement, or to a group of fixtures below ground level, and normally consists of a floating ball below a watertight seating. As long as the drainage outlet is clear the chamber in which the ball is located is dry and there is no obstruction to the flow, but if water cannot escape, or if it flows back through the outlet, the chamber fills and the ball rises and seals off the drain. The fixture concerned cannot then be used, since, obviously, if sewage is prevented from rising, drainage into the sewer is also prevented.

Indirect waste piping

Indirect waste piping is an extension of the method recommended for domestic drainage to cover elements of plumbing systems in large buildings employing the one pipe method.

With indirect waste disposal the drainage from a particular fixture is taken away from the fixture outlet and discharged over an air break into a gully or chamber located outside the building or in another part of it. Fig. 14 shows one type of arrangement for indirect waste disposal.

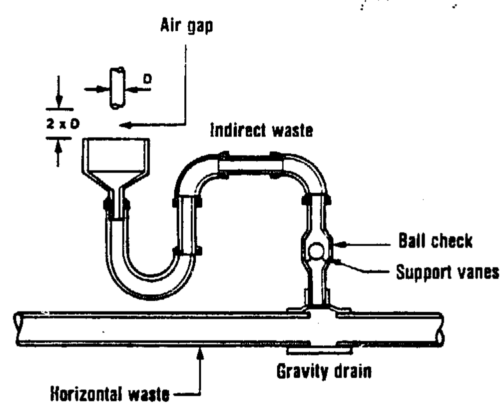


Figure 14.
Indirect waste arrangement.

In its simplest (domestic) form waste water from a sink or a bath-tub is taken from below the fixture trap through an external wall and discharged over a gully or a hopper head; thus (with the exception of the trap itself) the whole of the fixture outlet pipe is empty and open to the air. In the event of a blocked drain or if waste water backs up from another fixture, no sewage or sullage can reach the fixture outlet.

The same principle can be used to protect particularly sensitive areas in a large building in which the one-pipe system has been sanctioned for reasons of economy. Such sensitive areas might be rooms for the preparation of food (for consumption within or outside the building), or for the manufacture or use of sterile dressings or equipment.

If properly designed, installed and maintained, the one-pipe system is safe and hygienic. Adding indirect waste piping is only called for where the risks of contamination are so high as to warrant the additional precaution.

16. materials and workmanship

No plumbing system can be more durable than its component parts; no system, however well designed, can operate hygienically if the materials of which it is constructed are unsatisfactory.

Certain of the more industrialized countries have their own national standards for the materials and design of plumbing components and their own testing establishments to ensure that these standards are complied with. Other countries, which are members of the International Organization for Standardization (ISO), adopt the specifications and standards issued by that body as the minimum to be accepted for plumbing materials. Still others refer to standards laid down in one of the industrialized countries which they are prepared to accept as their own criteria.

The authority formulating a plumbing code of practice has to decide on the extent to which it wishes to control standards of materials and workmanship. Since it is unlikely to be able to cover every possible alternative - and certainly cannot be expected to anticipate new developments that may make new materials available on the market in the future - it may well prefer to adhere to the materials commonly in use in the country, but with a saving clause permitting it to approve alternatives if so requested.

In deciding on acceptable materials, the authority must take various factors into consideration. For example, the potable water piping, both underground and within the building, must not contain anything harmful - e.g., lead - that could be leached into the water; it must be of a strength capable of resisting the pressures to which it will be subjected; it should be proof against corrosion due to the soil in which it is laid or to the chemical composition of the water that it is to carry; and the methods of jointing should be sufficiently familiar to the plumbers who will install and maintain it.

In a number of countries the choice, as regards piping to dwellings, will be restricted to three commonly used materials - namely galvanized steel, copper and unplasticized polyvinylchloride. Of these the first is usually the cheapest but is somewhat clumsy for internal piping. If the water or the soil tends to be acidic there may be some danger from corrosion; however heavily galvanized the metal may be, there will always be some damage to the protective coating during transport, storage and installation. Fittings are simple and jointing is straightforward, but it may be wise to standardize sizes and threads, since any attempt to mix metric and nonmetric threads may lead to an unsound joint which looks safe when made but will give trouble in the future.

Copper is neater, of a smaller overall diameter for the same internal capacity, and more easily bent to shape. It is lighter, and therefore requires lighter brackets and supports; it is also easier to transport and handle. Against these advantages, it is more expensive (in most places) than galvanized steel and, being malleable, more subject to pilfering. It may be jointed by screwed compression fittings or by soldered unions. Copper piping is particularly useful when hot water systems have to be installed, but it is necessary to have copper cylinders, which are more expensive than galvanized steel ones. As has already been noted, there are dangers of electrolytic corrosion when two dissimilar metals are used in a hot water system; brass taps and fittings with copper piping and cylinder form a compatible system.

A number of types of plastic pipes are now on the market, and it is necessary to be particular as to the composition of any that are to be used for plumbing. Not only must they be capable of resisting internal water pressure and possible accidental damage when new, but they must not deteriorate under the conditions in which they will be used. Some plastics, for instance, will last almost indefinitely underground but will become hard and brittle if exposed to sunlight. They would obviously be unsuitable for connexions to an exposed roof tank.

The chief danger from certain types of plastic, however, is the possibility that toxic substances (especially salts of lead) have been used in their manufacture, and that these will leach into the water being carried. This is a complex problem which has been the subject of studies by research organizations in a number of countries. Particular care is necessary in choosing which types of plastic to sanction, since new compositions are continually becoming commercially available; at all events, it is wiser to wait until the ISO or another standardizing body has approved them before allowing their use in plumbing systems.

Provided that the requisite standards of health, safety and durability are met, plastic pipes have many advantages for plumbing systems (though great caution should be exercised before authorizing their use for hot water). They are light, easily handled and transported, and, because they are supplied in long lengths, need fewer joints than do metal pipes. They are therefore usually cheaper when installed, and have the additional advantage that they are relatively easily manufactured so that they can be locally produced in many countries that would have to import metal pipes. Jointing may be effected by screwed plastic compression joints or by cemented unions. Plastic pipes are usually more resistant to corrosion than are metal pipes, to which they may be jointed (using special fittings) with no danger of electrolytic action. Particular care must be exercised in their storage before use; if left uncovered under a tropical sun they may become brittle and unsuitable for future installation.

Plastics, as well as copper, galvanized steel and galvanized iron, may be used for other parts of the plumbing system, in which case the criteria for approval may be less rigid. If used for rainwater drainage, soil drainage and vent piping there is no danger from toxicity, and the pressures to be resisted will be much less than when mains water is to be conveyed. Hence a lower specification material may be acceptable, but precautions should be taken to ensure that there is no possibility of confusion with water piping.

The most commonly used material for underground drainage pipes is baked earthenware (sometimes called glazed stoneware or vitrified clay). It can be locally produced in almost any country, though not everywhere is it of a high enough specification for carrying sewage. Pipes must be watertight, which requires a good-quality clay mix, firing at the correct temperature, and glazing of high quality; they must also be sufficiently strong to withstand handling and laying, accurately rounded to permit watertight jointing, and straight enough to ensure an accurate gradient. Some relaxation of standards in respect of all these requirements may be allowed for rainwater drainage pipes.

Earthenware sewage-carrying pipes should preferably be laid on a concrete bed, and where conditions warrant (e.g, when they are laid in ground liable to movement, or near the surface, or under a highway or vehicle access) they should be haunched or completely surrounded with concrete. Concreting is not necessary for pipes carrying surface water, except where there is a danger of mechanical damage to the pipes, caused for example, by heavy traffic.

Other materials sometimes used for underground drainage include asbestos cement, plastic, vibrated concrete, and cast iron, each of which has its own properties - strength, considerable section length, resistance to corrosion, and availability - which makes them suitable under particular conditions. In general all these materials are more expensive than earthenware, but ease of laying may make some of them cheaper to install. Earthenware pipe is usually trowel-jointed with cement mortar; rapid joints with rubber, plastic or bitumen rings are available but require a very high standard of accuracy in pipe manufacture if they are to be satisfactory. When industrial discharges of a corrosive nature or of high temperature are to be carried particular care must be taken in choosing pipes and joints of suitable material to resist deterioration from these wastes.

With regard to fixtures, both design and material should be subject to approval. Some design features have already been mentioned - e.g., the provision of overflows to sinks and basins, the incorporation of a fixture trap or facilities for affixing one, and ensuring that incoming water is delivered through an air gap (i.e., that a tap outlet can never be submerged by water in the fixture). Local usage will often have a bearing on design: for example, whether pedestal pans or squats are installed will depend on the prevailing customs of the people in discharging faeces. In some areas it is necessary to provide a tap for personal ablutions close to the water-closet, in which case, of course, strict precautions against contamination of the system must be observed.

Sanitary fixtures should be durable, smooth and impermeable. There should be no hidden surfaces that can become foul, and both inside and outside surfaces should be accessible for cleaning. The most common and suitable material for domestic fixtures is glazed stoneware or other baked ceramics with a high glaze, though for bath-tubs and (occasionally) wash-hand-basins enamelled iron is often used, plastic baths are becoming more common, and of recent years stainless steel has become popular for kitchen sinks. Fixtures of these materials are not easy to manufacture, and in many developing countries they have to be imported. To avoid the use of scarce foreign currency, materials such as concrete can be used for the local manufacture of fixtures. However carefully made these are not as good as fixtures of the aforementioned materials, but it is necessary to be realistic and accept the fact that the choice is usually between the locally made item and none at all. Codes should therefore aim at ensuring that concrete fixtures are of the best possible design and finish; the smaller ones (sinks, basins) should preferably be vibrated to a dense mixture, while bath-tubs, shower trays and items cast in place should be tamped and trowelled to make the surface as impermeable as possible. Angles, both internal and external, should be rounded for ease of cleaning and inlet and outlet pipes should be integrally cast into the body of the fixture.

The extent to which concrete fixtures of this nature may be permitted in commercial and industrial premises must depend on the purpose for which they are used, but in general it should be remembered that concrete, however well made, can never be brought to a completely impervious finish, and that wherever food preparation is carried out concrete surfaces are almost certain to harbour salmonellae and other dangerous bacteria. Regular and careful painting of the surfaces helps to reduce the hazard, but can never produce conditions as hygienic as glazed earthenware fixtures. However, when these latter are used any crack or chipped surface exposes the permeable body of the material, which can become a breeding ground for pathogens, and therefore, under such circumstances, the fixture should be condemned if it is used at any stage of food preparation.

Standards of workmanship are extremely difficult to incorporate into the code; either a detailed description of every operation must be given - which would in itself constitute a textbook of plumbing - or some such generalization as "sound professional craftsmanship" must be used. Trying to enforce requirements phrased in such general terms presents many problems.

A solution to the difficulty is possible if a national plumbers' guild or some similar accepted examining institution exists (see Chapter 4). If this body approves standard methods for different plumbing operations as a basis for training and for the examination and certification of plumbers, then such methods can be referred to en bloc in the code as mandatory requirements, unless the authority gives its written approval to deviate from them in particular cases.

17. waste prevention and water conservation

From the health point of view water supplied to any premises should be ample for all the purposes for which it is to be used. Ideally it should be in such abundant supply that no restriction is necessary in the quantity available for flushing and cleansing. Such a situation obviously implies that the amount of raw water at source is virtually unlimited, and that the capacity of the public supply to pump, treat and distribute it is adequate for all needs.

These conditions cannot always be fulfilled in practice and consumption may therefore have to be restricted (as will be disussed later), but a clear distinction must be made between excessive consumption and wasted water. Some wastage appears to be inevitable in every water supply system, and the term "waste prevention" is used for measures intended to reduce losses to a minimum. (In this context, and throughout the present chapter, the term "waste" refers to water that escapes from the system unused, and not to human wastes or other forms of used or degraded water that are carried away by drains or sewers).

It is safe to say that no public supply is completely proof against wastage; not even the best designed and most carefully constructed system can remain absolutely watertight throughout its life. The more efficiently run undertakings maintain a continuous programme of inspection and implement remedial measures to discover and stop leakage. This is done for two principal reasons - economy, because losses of water represent losses of cash, and health, because leaks that allow water to flow out of the system can also provide the means of entry for pollution. It is of little use, however, to maintain a tight control over the public mains if wastage is taking place in privately owned connexions, and this is one of the justifications for enforcing plumbing codes of pratice.

Wastage below ground is difficult to detect and expensive to remedy, and the enforcement of high standards of materials and workmanship is the only practicable means of prevention. Leakage from pipework within a building is usually self-evident, and is frequently so damaging to the structure and to internal decorations that it is in the interest of the owner of the property to have this remedied promptly, especially since a leak can get progressively worse as the escaping water increases the size of the orifice through which it emerges. In certain types of property - e.g., in poorer dwellings, or in industrial or commercial premises - this argument may not apply and powers of enforcement may be necessary to compel those responsible to undertake repairs.

There is another type of wastage that is very difficult to control without the cooperation of the building's occupiers - namely that due to leaking washers or ill-adjusted fixture fittings. Because the waste water is conveyed through the fixture to the drain or is discharged through an overflow it may cause no nuisance within the building, and therefore there is little incentive for the property owner to incur the expense of repair. In older properties, especially, the total wastage due to this cause may amount to a very considerable flow, which is difficult and expensive to detect and identify. The usual procedure for tracing these discharges is a combination of district metering and inspection of the mains and services during the early hours of the morning with some form of listening device, followed by more detailed examination of suspect properties during the day.

The actual cost of replacing worn washers and adjusting leaking fittings is very little once they have been traced, and many water authorities find that it pays them to carry out these simple remedial measures free of charge to consumers, thus encouraging them to report such faults at an early stage.

Other authorities pin their faith on the installation of individual meters to all properties on the ground that the cost of wasted water will be borne by individual consumers rather than by the public undertaking, and this fact will provide an incentive for consumers to repair leaks promptly and also to avoid excessive use of water. This argument has been shown to be effective in the case of large commercial and industrial premises and in multiple dwellings and similar properties where there are facilities for inspection and repair by maintenance staff. In the case of single dwellings (which usually constitute the greater part of the total demand on a supply) the system does not often work so well in practice, and individual house metering is more commonly justifiable in those areas where the scarcity of source water warrants a tight control over the quantities supplied to each consumer.

It must be remembered, firstly, that meters do not in themselves produce water, and, secondly, that they are neither cheap to install nor to maintain. It is not unknown for undertakings contemplating the introduction of meters in domestic premises throughout their supply area to find that for the same outlay they can enlarge their treatment and distribution systems and thus augment the quantities available to consumers by more than the amount of wastage that the metering might prevent. The provision and installation of meters by no means represent the final cost of their introduction: they have a limited life and are a continuously depreciating investment; facilities for repair and calibration must be provided (involving workshops and trained servicing staff), and a team of meter-readers, with supporting clerical personnel, is also needed.

Provided that the water itself is available in sufficient quantity, and that the public supply system is capable of treating and distributing it to all consumers, it is better from a health point of view that as little restriction as possible is placed on its legitimate use. Ample supplies are especially important in the homes of large families who are often the poorest and most likely to be restrained in their use of water through a "rationing by the purse" induced by metering. On the other hand, in premises where special or excessive use may be expected (e.g., swimming pools or extensive garden watering) meters are a convenient way of ensuring that such water is paid for, and this can be achieved by a differential rate - i.e., a basic rate for a fixed quantity per month according to the number of occupants of the building, any amount consumed in excess of this being charged for at a higher cost per unit delivered.

For water authorities individual house metering has another function, in that it detects and identifies leakage, though only if every single connexion has its own meter. A comparison of the quantity of water entering a district or section of the mains system (through a recording meter inserted in the mains) with the sum of the quantities registered on the individual outlets (as shown on the house meters) during the same period provides a check on any underground leakage through mains and connexions in that area. When meter readings for a property are higher than average it is possible, by shutting off all fixtures for a time and checking for meter movement, to see whether wastage is occurring in the plumbing system, and this can easily be done by the occupier himself.

Apart from leakage and the loss through faulty washers and fixture fittings, excessive and wasteful use may make heavy demands on the water supply. In arid areas especially, it is worth incurring considerable expense and effort to combat this form of water loss; even where public supplies are ample there may be periods of drought when economies have to be made to ensure that there is enough water for everyone. There are a number of actions that the authority can take, the first and most important being to secure the cooperation of consumers through publicity, education and other forms of public relations. Larger consumers may be persuaded to install devices to cut down water use, such as spray faucets for hand and vegetable washing, showers instead of bath-tubs, and various forms of economy in the use of process water.

In domestic properties one of the biggest single uses is the water-closet flushing cistern, which often accounts for a third of the daily household consumption. During temporary emergencies it is often possible to make appreciable savings in the water used by adjustment of the ball valve or by displacement of some of the water in the cistern by inserting a brick, a water-filled plastic bag, or similar device. Such measures should be regarded as temporary only; if a water-closet pan has been specifically and properly designed to be cleansed thoroughly with a particular quantity of water, it follows that the consistent use of a lesser flush will not always clean it sufficiently.

For long-term economies it is better, therefore, to use the plumbing code to limit the capacity of the flushing cistern and require that the pan is designed to be self-cleansing with the lesser amount. There are two main types of flush - high level and low level. The first, set at a minimum height of about 2 m (6 ft) above floor level, makes use of the velocity of the falling water to achieve an adequate flush and hence uses less water than the low level cistern situated just above the rim of the pan. Fashion rather than utility has made the low-level suite more popular than the high-level (though it is also undoubtedly less noisy), but where water conservation is essential there may be justification for making standard the less modern high-level type.

A recent development of the high-level cistern makes it possible to reduce still further the daily consumption for each water-closet by providing a flush of half the cistern's capacity when liquids only have to be disposed of, and the full amount when the pan also contains solids. The individual using the water-closet either pulls and immediately releases the handle (in which case about 2 litres, or about half a US or UK gallon is delivered), or holds the handle down until the flush finishes (to deliver 4.5 litres, or about 1 US or UK gallon. Since a low-level cistern normally operates a flush of 9 litres (or about 2 US or UK gallons) or more it will be seen that there is considerable potential saving in a household where each member uses the water-closet several times a day, as well as in sanitary facilities at factories or in public buildings. Experiment has shown that it is acceptable and easily operated by the public provided that a small notice giving simple directions is affixed to the wall close to the handle.

In areas of extreme water scarcity it may be necessary to install chemical toilets instead of water-closets. There are a number of types, but most are self-contained and do not strictly come under the heading of plumbing fixtures, so they will not be discussed here.

Water authorities adopt various expedients to reduce consumption by the public during periods of water shortage. One of the most common, and least to be recommended, is to make supplies intermittent. Mains in the whole or part of the system are shut down completely during certain hours of the day. As a consequence negative pressures develop, with all the concomitant health hazards; deposits of rust, detritus and other sediments within the mains are stirred up and carried in suspension when the flow resumes; air may be drawn into the system to cause airlocks or water-hammer; and sudden calls for fire fighting cannot be met without undue delay. It is also doubtful whether significant savings result, since consumers fill bath-tubs and containers in anticipation of shutdowns, and much of this reserve water is wasted when the supply returns to normal.

A more positive precaution is the control of mains pressure to the minimum necessary by means of pressure-reducing (or flow-regulating) valves. This can result in appreciable savings and is a practicable solution where the area is reasonably flat and where buildings are of similar type, but in hilly conditions or where tall buildings have to be served, care must be taken that cutting down pressure does not leave certain properties unserved. In these circumstances it may be preferable to control the flow to individual premises in the areas of higher pressure by the insertion of washers with regulating orifices adjacent to the water authority's stop valve for each service.

In areas of chronic water shortage in different parts of the world experiments have been carried out with various types of dual water systems, in which a separate nonpotable supply is used for water-closet flushing, car washing, garden watering and other uses where quality is (relatively) immaterial, leaving the potable supply for human consumption, food preparation and personal hygiene. Such a system should not be authorized without stringent precautions against misuse and cross connexions. The principle is more applicable to large-scale consumers, treated sewage effluent is sometimes used as cooling water in heavy industry (its use should never, of course, be permitted where food is manufactured or processed). Raw river water may be piped and used for such purposes as sewer flushing or fire fighting, but it is worth noting that epidemics have been traced to the use for domestic purposes of water from fire hydrants in the poorer sections of tropical cities. The so-called "grey water" system (Fig. 15), in which sullage water from bath-tubs and sinks is used for flushing water-closets or for garden watering, has been tried out on domestic premises, but again there are considerable health hazards unless the system is installed and operated under strict control. In general, it is recommended that plumbing codes should be framed to exclude any dual water system, which should only be permitted by special licence and under certain conditions - if at all.

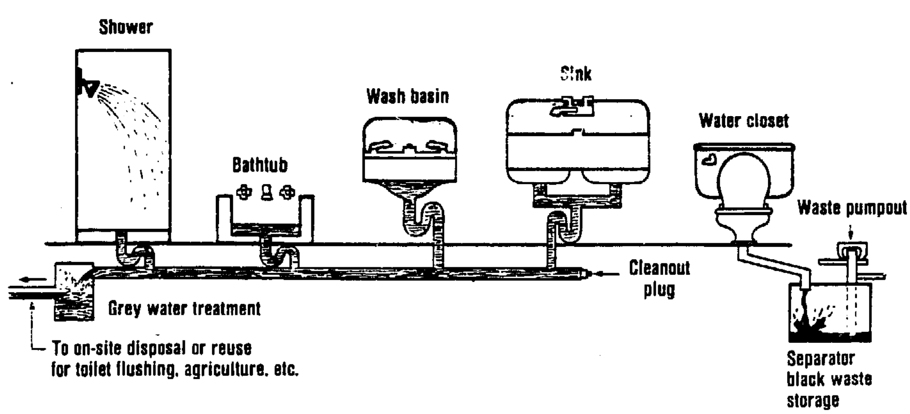


Figure 15.
Greywater-blackwater system.

To return to the point made earlier - the most effective way of reducing consumption is to obtain the willing cooperation of the public through educational programmes and other public activities. Economies in use and the prompt repair of leaks and adjustment of dripping fittings and taps are usually attainable when consumers realize the significance to the community and themselves of the savings thus made, which often equal those that can be achieved by the much more costly installation and operation of mechanical devices. This should always be the first line of approach when water has to be conserved.

18. intermediate and communal sanitation

The formulation and enforcement of a plumbing code of practice is normally dependent on the availability of public water supplies and sewerage. Provided that no nuisance is caused to neighbouring properties it is difficult to justify undue interference with those who make their own arrangements for domestic water supplies and excreta disposal in the absence of public services.

There are, however, certain circumstances under which some form of intermediate control may be desirable. These might include situations in which mains and sewers, though not immediately available, are planned to be installed in the near future (e.g., on the outskirts of an expanding town where mains extensions are imminent), or those in which water supplies but no sewers have been constructed.

In such cases it will be more economical in the long run, both to the individual householder and to the authority, if any private intermediate arrangements are so designed and installed that they are capable of being incorporated with the minimum of adaptation into a plumbing system complying with the code when public water and sewer services eventually become available. For example, a private dwelling might be supplied from a well on the property from which water is pumped to a roof cistern and distributed to fixtures within the building by internal piping. It will obviously be advantageous if, when mains water is brought to the property in the future, all that has to be done is to carry a connexion up to the same cistern and disconnect the pump from the well. This can be properly done only if the internal piping and fixtures already comply with the relevant provisions of the plumbing code.

Similarly, drainage that is taken to a septic tank or cesspool should be so designed and installed that it can be diverted to a future sewer from a convenient manhole with no alteration necessary other than the disconnection and filling in of the disposal tank.

A form of sanitation particularly suitable to crowded cities is the aqua privy (Fig. 16), consisting of a single underground septic tank upon which are built a number of individual latrines, the outlets from which drop vertically through the tank roof and discharge under the surface of

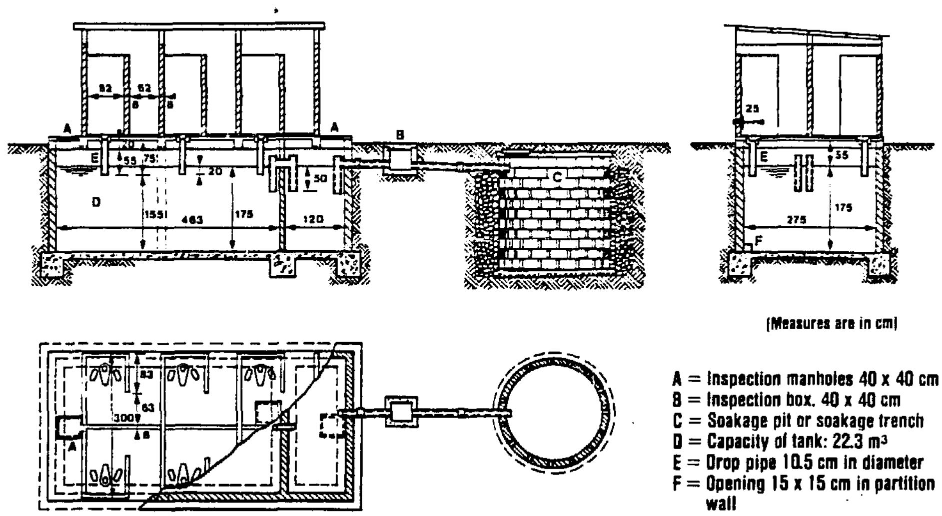


Figure 16.
Communal aqua-privy.

the septic liquid below. Properly designed, constructed and maintained, an aqua privy can serve the needs of four or more households, each having its own private cubicle containing a latrine. Faecal solids are broken down and liquified and the effluent liquid is comparatively innocuous. However, under crowded conditions to which this type of waste disposal is especially suited, even the removal of this liquid may present a problem if the subsoil is impervious. A drainage system to collect the effluent from a number of aqua privies may be constructed at a fraction of the cost of sewers; because only liquid is discharged and there is consequently no danger of blockage, small-diameter pipes may be used for the drains. If, however, at some future time it is proposed to install conventional waterborne sanitation - i.e. water-closets and sewers - the effluent collection drains will have to be entirely scrapped since they will be inadequate to carry sewage.

As noted in Chapter 2 the first goal or principle of plumbing is that every occupied building should have an internal water supply: until this is achieved "plumbing", in the sense in which it is used in these guidelines, is impossible. There are various intermediate stages between the use of an unprotected natural source and the attainment of this goal. The first improvement that may be made in a community is the provision of a safe source (e.g., a well or protected spring) from which water has to be drawn; the second may be the provision of a hand pump or other device through which water can be delivered directly into the carrying container. The next stage may be the establishment of a central point to which water is pumped, and at which it is stored and possibly chlorinated before being collected. A further improvement comes when treated water is piped to public standposts close to the homes of those who will draw their water from them, and another intermediate stage is the piping of water to a private standpost within each property or compound. The final stage before the installation of plumbing and plumbing fixtures is a single tap within the house, usually over a kitchen sink.

Each of these stages marks an improvement in the environmental health situation, probably the two most significant being the initial protection of the source and the bringing of water to individual properties, thus eliminating the need for carrying household supplies and storing them within the home. In many cases some (or all) of these stages are bypassed; an example is when a complete new public supply is installed in a community that previously had no protected water source. More commonly, economic constraints make it necessary to provide a somewhat more restricted service initially so that the water supply grows and advances with the community's improving social conditions.

Under these circumstances it is important not to lose sight of the goal of internal water supplies to every household, and to ensure that each stage of improvement is carried out with the next step in mind. For instance, mains laid to public standposts should not be of a size merely adequate to serve those standposts, but should be of sufficient carrying capacity to permit house connexions to be made later. It this is not done, some small immediate savings may admittedly be made, but the necessity for replacement by larger-diameter pipes will be a definite obstacle to the implementation of the next stage of improvement.

Factors other than installation costs may quite legitimately halt improvements at an intermediate stage. In overcrowded or slum areas the potential cost of internal plumbing might easily be more than the value of the properties to be served, and it would then be logical to halt water supply improvements at the public standpost stage pending the renovation and rebuilding of the insanitary housing. Epidemic disease, however, will not wait for town planning, and it is those very slum dwellers who are most in need of facilities for personal hygiene, clothes washing, and the like. Thus the provision of communal latrines, bathhouses and laundries may rightly be regarded as intermediate sanitation facilities, their expense being justified by the improvement in the health of the public as a whole as well as of those who will personally use them.

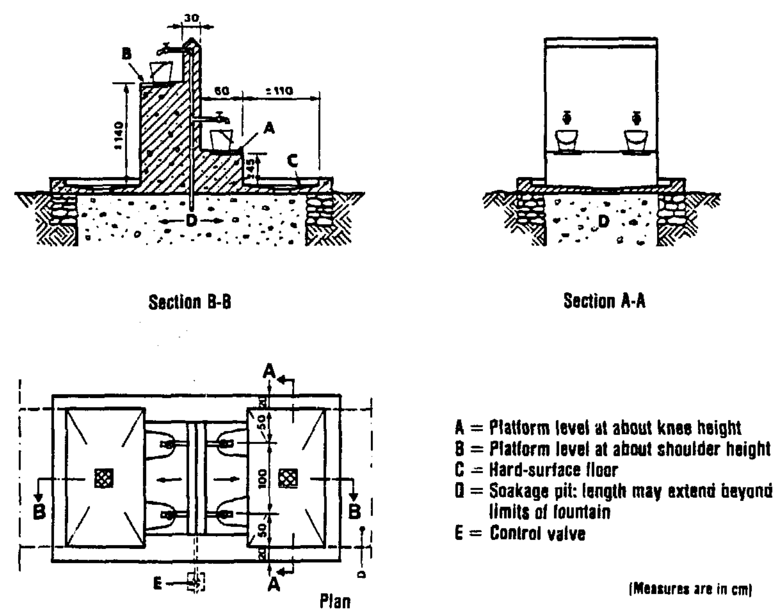
Plumbing in and for communal facilities needs to be more robust than that installed on private premises, and in the design precautions must be taken against vandalism, theft and misuse. Brass faucets are particularly subject to pilfering if they can be easily unscrewed, and it is worth drilling a hole in the threaded union and fastening with a set screw or rivet. Standposts and exposed pipework may be embedded in concrete, even though maintenance is thereby made more difficult; high-level flushing cisterns and shower control valves may be mounted above the ceiling with only the chain and handle visible in the cubicle. The seats of pedestal water-closet pans can be made of (relatively) unbreakable wood, preferably open at the front and fixed, rather than of hinged plastic. Control valves, whether below ground or mounted in the building, are better enclosed in lockable boxes. Similar considerations may govern the design of truly public facilities, such as those erected in markets or other places of public assembly.

There are various types of public standposts; selection should be governed by suitability for local usage. The simplest and cheapest - a vertical galvanized pipe upon which one or two faucets are mounted - is also the most wasteful and the most liable to misuse. In addition to the drained, sloping apron that should surround every standpost a step or shelf should preferably be moulded below each outlet so that there is a gap of a few centimetres only between the emerging water and the top of the most commonly used carrying vessels (often a kerosene can or locally made earthenware pot), thus reducing spillage to a minimum. Moreover, if the container is raised in this way it is easier to lift it on to the shoulder or head for carrying, and a direct support prevents buckets from being hung by their handles on the tap itself (see Fig. 17).

Faucets may be of the conventional screw-down type (which are frequently left running between fillings) or spring-loaded. The latter, in theory, automatically shut off as soon as the user's pressure is removed, but local ingenuity with a piece of cord or wire and a wooden wedge soon converts them to a constant-running outlet. By fitting them flush against a vertical concrete or masonry wall this is made more difficult if there is insufficient clearance to pass the cord behind the pipe. It also lengthens the life of the tap if it is so mounted that pressure must be applied horizontally rather than vertically. Various patented types of waste-proof taps are available which deliver a fixed quantity of water from a single pressure, but these are not cheap and only the more robust patterns stand up to continuous use.

The plumbing of multiple latrines, bathhouses and laundries should comply with the general principles of the code with regard to cross-connexions, back-siphonage, etc. The provision of storage tanks assumes added importance, since most of these buildings are subject to peak use: by providing each with its own storage tank the flows are evened out and economies may be possible in the delivery mains and connexions. In many arid areas it is even customary to provide storage at groups of standposts for the same reason.

Above all, the maintenance of the installations, as with all plumbing systems, will materially depend on the cooperation of those using them. It is worth making considerable efforts to build up a sense of communal ownership and pride of possession (especially among children by, for example, talks at schools) so that cooperation is voluntarily given and enforcement unnecessary. In this way communal sanitary facilities may be kept clean and undamaged with the minimum of attendance and supervision.



Public standposts should be constructed of the most durable materials possible because no part of the water system will be required to take so much abuse. It is usually possible to construct the platform and faucet support so that only the most excessive abuse will damage it. The weakest part is the faucet itself. This should be the strongest available.

Figure 17.
Possible arrangement of public standpost.

annexes

1. reviewers

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Note: The titles of the reviewers are those that applied at the time that the review was done.

2. disinfection procedure for plumbing systems

Disinfection of a plumbing system is normally achieved by filling the supply tank and all internal pipework with a solution containing 50 parts per million of free chlorine, allowing this to stand for at least 12 hours and then flushing it to waste. Under special circumstances the period may be shortened to 3 hours, but the solution used should then contain at least 300 p.p.m. of free chlorine. It is possible to use other proprietary disinfectants instead of chlorine, but care must be taken to ensure that they are not toxic and have no adverse effects on the pipes or fittings. A chlorine based compound, such as bleaching powder or sodium hypochlorite, is the most commonly used agent, and the use of one of these is assumed in the following notes.

First it is necessary to calculate the quantity of disinfectant to be used. This depends upon two factors - the volume of water contained in the system while no draw-off is taking place, and the percentage of free chlorine in the compound chosen.

The cubic capacity of the pipework can only be obtained by measuring the lengths of pipe of different diameters and multiplying by their cross sectional areas. To calculate the figure accurately is usually a laborious process, and it is more practical to make a generous estimate since the disinfectant solution may with benefit be over strong, but should not be weaker than that specified. To the pipework capacity must be added the volume of the supply cistern and any flush tanks connected to the system.

To obtain a 50 p.p.m. solution, 50 g of free chlorine per 1000 l (7 oz per 1000 US GAL; 8 oz per 1000 UK gal) will be needed. The strength of the compound to be used (whether solid or liquid) should be known and the quantities adjusted according to the percentage of free chlorine. If, for example, a bleaching powder of 25% available chlorine is the agent chosen, 200 g of the compound will be required per 1000 litres of solution (1.7 lb per 1000 US gal; 2 lb per 1000 UK gal). If the compound is in solid form it will be expedient to dissolve it to a creamy liquid immediately before use.

Before dosing starts all pipework should be flushed out, the incoming mains supply shut off, and the system emptied by opening valves on all fixtures. The 'dead' space in the supply tank below the lowest draw-off point should be emptied and cleaned out. Prior to emptying, all the occupants of the building should be notified of the expected length of interruption of supply so that water for use during that period may be drawn off and stored. They must also be warned against using any flush tank or other fixture while disinfection is taking place.

With all fixture taps closed, water from the main is readmitted to the storage tank and the prepared disinfectant gradually added to the incoming supply close to the ball valve to ensure thorough mixing. Most, but not all, of the disinfectant should be added in this way until the tank is full. Water should then be drawn off from each fixture in turn until chlorine (as evidenced by the smell) emerges, after which the fixture taps are shut and left undisturbed for 12 hours. Flush tanks should be operated until the water they contain is chlorinated. The supply tank should then be topped up (using the remainder of the concentrated disinfectant) and the incoming supply shut off once more.

At the end of the 12 hour contact period the system is once more emptied through the fixtures, mains water re-admitted to the supply tank, and fixtures such as sink or wash basin taps opened and allowed to run until chlorine cannot be smelled or tasted. It is unnecessary to do this to WC's or other fixtures where the water will not be drunk or come into contact with the skin.

In buildings where no supply tank is installed and fixtures are supplied directly from mains pressure, the procedure is more complex, calling for the use of a force pump, and this will usually be carried out by the health authorities, or to their special requirements.

3. fixture unit calculation for multiple dwellings

The 'fixture-unit' concept is a method of calculation of water supply and drainage piping within large buildings by which economies may be made in construction costs. Theoretically all pipes should be of such a size as to be capable of serving the fixtures to which they are connected even though all other fixtures in the building are being operated at the same time. In practice the chances of them all being in use together are remote and the piping design criteria may be relaxed to take account of this.

A fixture-unit value (f/u) is assigned to each type of fixture based on its rate of water consumption, on the length of time during which it is normally in use, and on the average period between successive uses. Some examples of fixture-unit values assigned to the most common fixtures are given in Table 4. When these are added their total gives a basis for determining the flow that may be expected in a water or drainage pipe to which two or more fixtures are connected. The total is then reduced by a factor, usually in the region of 0.6 to 0.7, but depending upon the degree of simultaneous use protection considered necessary under local conditions.

The total number of f/u's connected to each branchpipe are then added, multiplied by the factor referred to above, and the result is used to calculate the flow in water or drainage pipes in accordance with tables of which the following are examples. If included in, or annexed to, a plumbing code these tables should be detailed for a larger schedule covering the whole range of fixture-unit values to be expected; examples may be found in various national codes, such as those listed in the bibliography, Annex 5.

From Table 5 the size of the water pipes may be calculated using normal design principles (allowing for head loss, friction and other factors). Fixtures using both hot and cold water (e.g. baths, sinks) should be assumed to take equal quantities of each for design purposes - thus a bath would be counted as 1 f/u on the cold water system, 1 f/u on the hot water. Supply piping would be calculated accordingly, while the total figure of 2 f/u would be used to design the drainage piping.

From Table 6 the size of internal and external drains may be calculated according to the total number of fixtures discharging into each section, with the proviso that underground drains shall not be smaller than 100 mm (4 in) diameter, and that no internal branch or drain of less than 80 mm (3 in) diameter should carry the discharge of more than 2 water closets.

An alternative to the fixture-unit method for calculating flows is in use in some French-speaking countries. This method assigns individual flow values to each fixture, multiplies the cumulative flow so obtained by a simultaneous use factor obtained from a nomogram and curve, and selects pipe sizes by reference to precalculated tables. This approach is fully described in 'Traitê Pratique de Plomberie' by H. Charlent (see bibliography, Annex 5).

Table 4
Fixture-unit values for some common plumbing fixtures.

Fixture	F/u
Bath or Shower	2
Bidet	2
Clothes washer (automatic)	3
Drinking fountain	3
Kitchen sink	$1\frac{1}{2}$
Urinal or Water Closet (with flush tank)	3
Urinal or Water Closet (with flush valve)	6
Wash basin	1

Table 5
Peak water demand of plumbing fixtures.

No. of f/u's	l per sec	US gal per min	UK gal per min
5	0.23	3.65	3.04
10	0.34	5.39	4.49
20	0.54	8.56	7.14
50	1.13	17.94	14.93
100	1.67	26.51	22.07

Table 6
Maximum loads in fixture-units for horizontal fixture branches and building drains or sewers.

Diameter of Drain Pipe		Fixture Branch	Building Drain or Sewer			
mm	in	Min. Slope 2% (1 in 50) f/u	Slope 0.5% (1 in 200) f/u	Slope 1% (1 in 100) f/u	Slope 2% (1 in 50) f/u	Slope 4% (1 in 25) f/u
32	$1\frac{1}{4}$	1	-	-	-	-
40	$1\frac{1}{2}$	3	-	-	-	-
50	2	6	-	-	-	26
65	$2\frac{1}{2}$	12	-	-	-	31
80	3	32	-	36	42	50
100	4	160	-	180	216	250
150	6	620	-	700	840	1000
200	8	1400	1400	1600	1920	2300

4. rainwater intensity and roof drainage

The variable factors in selecting the size of rainwater guttering are:

1. The intensity of the rainfalls to be catered for.
2. The slope at which the gutters are to be fixed.
3. The area of the roof surface to be drained by each gutter.

From a practical point of view an upper limit of rainfall intensity must be assumed; during downpours of higher than the assumed concentration, surplus rainwater will overflow the guttering but will add comparatively little to the general deluge. In the following illustrative tables the maximum intensity has been assumed to be 100 mm (4 in) per hour - a high figure. In the code the figures would have to be recalculated to suit an intensity considered realistic under local conditions.

The slope of the gutter will be limited by the vertical gap between the eaves and the gutter at the lower end of the run. If this gap is much greater than the diameter of the channel small discharges will be blown clear of the gutter by quite moderate winds. A slope of 1% (1/8 in per ft run) may be taken as an average in which case an eaves length of 10 metres will result in a vertical gap of 10 cms (4 in in 33 ft). Lengths appreciably over this will require two or more vertical downspouts with consequent increase in cost. In Table 7 the roof areas which can be drained by gutters installed with slopes of 0.5%, 1% and 2% are shown for purposes of comparison. This table can be adjusted to allow for other slopes permitted under the code and can also be extended as needed to cover gutters of large diameters.

The area of roof to be drained is calculated on the basis of the horizontal projection and not on the actual surface of a sloping roof.

Table 8 shows the maximum roof area that can be drained by five common sizes of vertical downspouts or leaders when the rainfall intensity is 100 mm (4 in) per hour. These are suitable either to take the discharge from guttering or from flat roofs drained directly into these leaders. The figures should be adjusted to apply to discharges from storms of different intensity according to local conditions and experience.

Table 9 shows the total roof area, the discharge from which may be conveyed by 'horizontal' drains (above or below ground) into which one or more vertical downspouts are connected, and which may also serve to drain paved areas such as courtyards. The same storm intensity has been assumed and three gradients - 1%, 2% and 4% - have been tabulated. Again, amendments and extrapolations should be made to suit local conditions and the requirements of the code.

Table 7
Roof areas drained by semicircular gutters.

Rainfall Intensity 100 mm (4 in) per hour

Guttering dia.		Roof area drained with gutter slopes of:					
		0.5% (1 in 200)		1% (1 in 100)		2% (1 in 50)	
mm	in	m^2	ft^2	m^2	ft^2	m^2	ft^2
80	3	16	170	22	240	32	350
100	4	33	360	47	510	67	720
125	5	58	625	82	880	116	1250
150	6	89	960	126	1360	178	1920

Table 8
Roof areas drained by vertical downspouts.

Storm Intensity 100 mm (4 in) per hour

Dia. of downspout		Roof area drained	
mm	in	m^2	ft^2
50	2	65	700
65	$2\frac{1}{2}$	120	1300
80	3	205	2200
100	4	430	4600
150	6	1255	13500

Table 9
Capacities of horizontal storm drains.

Storm Intensity 100 mm (4 ins) per hour

Diameter of Drains		Area to be drained with a slope of:					
		1% (1 in 100)		2% (1 in 50)		4% (1 in 25)	
mm	in	m^2	ft^2	m^2	ft^2	m^2	ft^2
80	3	75	820	110	1180	150	1620
100	4	175	1880	245	2640	350	3770
150	6	495	5350	700	7550	995	10700
200	8	1070	11500	1515	16300	2135	23000

5. bibliography

The following are some suggestions for sources of additional information on various aspects of the subjects discussed in these guidelines. The list is not comprehensive and should be regarded as providing representative samples of a large literature on plumbing, codes of practice and allied problems in various languages and relating to differing geographical and other conditions.

1. National Codes of Practice and Model Codes

CANADA, NATIONAL RESEARCH COUNCIL OF CANADA, ASSOCIATE COMMITTEE ON THE NATIONAL BUILDING CODE. Canadian Plumbing Code 1970. First printing 1971 and subsequent revisions. Ottawa.

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TRINIDAD AND TOBAGO. National Plumbing Code. Regulations made under the Water and Sewerage Act 1965, Sec. 66(7), and issued by the Water and Sewerage Authority

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U.K. MINISTRY OF HOUSING AND LOCAL GOVERNMENT. Model Water Byelaws. London, H.M. Stationery Office, 1966.

U.S. NATIONAL ASSOCIATION OF PLUMBING, HEATING AND COOLING CONTRACTORS. National Standard Plumbing Code, Washington, D.C., 1971.

INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS. Uniform Plumbing Code. Los Angeles, 1970.

2. Standards for Plumbing Materials

Standards are issued for a large variety of plumbing materials by the International Organization for Standardization (ISO), Geneva, and by affiliated national standard-setting bodies in 62 of its member countries.

3. Studies on Special Problems

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index

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