14. Design of plumbing systems for multi-storey buildings

For plumbing purposes, the term “multi-storey” is applied to buildings that are too tall to be supplied throughout by the normal pressure in the public water mains. These buildings have particular needs in the design of their sanitary drainage and venting systems. Water main supply pressures of 8–12 metres (25–40 feet) can supply a typical two-storey building, but higher buildings may need pressure booster systems. In hilly areas, the drinking-water supply pressures will vary depending on the ground elevation. In these cases, the water authority may have to specify areas where particular supply pressures can be relied upon for the design and operation of buildings. Where a building of three or more storeys is proposed a certificate should be obtained from the drinking-water supply authority guaranteeing that the present and future public drinking-water supply pressure will be adequate to serve the building. If the public water pressure is inadequate, suitable means shall be provided within the building to boost the water pressure.

14.1 Systems for boosting water pressure

Pressure-boosting systems can be of several different types:

- pumping from a ground level or basement gravity tank to a gravity roof tank;
- pumping from a gravity storage tank or public water main into a hydro-pneumatic pressure tank that uses captive air pressure to provide adequate drinking-water supply pressure;
- installation of booster pump sets consisting of multiple staged pumps or variable speed pumps that draw water directly from a gravity storage tank or the public water main. Multistage booster pump sets typically include discharge pressure regulating valves to maintain a constant drinking-water supply pressure.

Written approval should be obtained from the appropriate authority before any pump or booster is connected to the supply. Where booster pump sets are permitted to draw directly from public water mains, the public drinking-water supply must be adequate to meet the peak demands of all buildings in the area. Otherwise, there is a high risk of backflow and subsequent contamination of the mains from buildings not equipped with a booster pump. Building booster

pumps are not a solution to the problem of inadequate drinking-water supply. Where public drinking-water supply systems are overburdened and cannot provide adequate pressure on a continuous basis, water must be stored on site during periods when adequate pressure is available to fill a gravity storage tank. The size of the storage tank will vary according to the daily water demand of the building, and the availability of adequate pressure available in the public water mains. It should not be excessively oversized to avoid stagnation due to inadequate turnover.

Multi-storey buildings can usually be divided into zones of water pressure control. The lower two to three storeys can generally be supplied directly from the pressure in the public water main. Upper storeys, usually in groups of five to eight storeys, can be supplied from pressure-boosted main risers through a pressure reduction valve for each group. Systems can be up-fed or down-fed. Up-fed systems usually originate from a pressure booster pump set or hydropneumatic tank in the basement of the building. Down-fed systems usually originate from a rooftop gravity tank. Where a building is divided into water pressure zones, care must be taken not to cross-connect the piping between two or more zones. This is a particular problem when domestic hot water is recirculated from a central supply system.

Where hydropneumatic tanks are used for storage, the tank is filled to one third to a half full by a float level device that controls the drinking-water supply source (a well pump or pressure booster pump). The pressure is maintained at the desired operating level by an air compressor. As the building uses water from the tank, the water level and air pressure drop. When the water level drops to the "on" setting of the float level control, the well pump or booster pump starts and raises the water level in the tank to the "off" level. This restores the pressure in the tank. If some of the captive air above the water has been absorbed by the water, the air compressor starts and restores the air charge, raising the system pressure to the normal level. Hydropneumatic tanks are typically made of steel or fibreglass and must be rated for the system operating pressure. Steel tanks must have a protective coating of suitable composition for drinking-water contact on the inside to protect the tank from corrosion and avoid contaminating the water. They should be checked on a regular basis to ensure that the protective coating is intact and the water remains potable.

Smaller hydropneumatic tanks can also be used to help control pressure booster pumps, allowing them to be cycled on and off by a pressure switch. The captive air within the tank keeps the system pressurized while the pump is off. When the water pressure drops to the "on" pressure setting, the pump starts and raises the volume and pressure of the water in the tank. No air compressor is needed where tanks have a flexible diaphragm between the air and the water in the tank, charged with air at initial start-up. The size of pressure tanks for booster pumps must match the capacity of the pump and the peak system

demand so that the pump "off" cycle is longer than the "on" cycle and the pump does not cycle too frequently.

14.2 Drainage systems

14.2.1 Drainage system considerations

In the drainage system for a multi-storey building, the drains from the plumbing fixtures are connected to vertical drain stacks that convey the waste and sewage to below the lowest floor of the building. The fixture drain traps must be vented to prevent their water trap seal from being siphoned by negative pressure or blown out by positive pressure in the drain piping. The fixture vent pipes must extend through the roof to outdoors. They can be run individually or be combined into one or more vents through the roof. Where buildings are over 10 storeys high, the drainage stacks require relief vent connections at specified intervals from the top, and connected to a vent stack that terminates above the roof. This relieves and equalizes the pressure in the drainage stack to maintain the water seal in traps serving plumbing fixtures.

Wherever possible, the sanitary drainage system from a building should discharge to the public sewer by gravity. All plumbing fixtures located below ground level should be pumped into the public sewer or the drainage system leading to the sewer. The pump line should be as short as possible and looped up to a point not less than 0.6 metres (24 inches) above ground level to prevent back-siphonage of sewage. The pump discharge rate should be controlled so as not to cause scouring of the internal bore of the pump line or the drainage or sewer system into which it discharges. High-velocity discharge rates may also cause the flooding of adjoining plumbing fixtures or overloading of the sewer itself. The sump pits for sewage pumps must have sealed covers, be vented to outdoors and have automatic level controls and alarms. Sewage pumps in multiple dwellings and in multi-storey dwellings should be duplex, with each pump having 100% of the required pumping capacity for the building. Alternatively, an approved vacuum drainage system may be considered.

14.2.2 Vacuum drainage systems

In a vacuum drainage system, the differential pressure between the atmosphere and the vacuum becomes the driving force that propels the wastewater towards the vacuum station. Table 14.1 provides a summary of the advantages and disadvantages of vacuum drainage systems. Table 14.2 provides information on specific installation and operation requirements. Vacuum drainage systems should be considered when one or more of the following conditions exist:

- water shortage;
- limited sewerage capacity;
- where separation of black water and greywater is desired;
- where drainage by gravity becomes impractical;

TABLE 14.1 ADVANTAGES AND DISADVANTAGES OF VACUUM SYSTEMS (VERSUS GRAVITY SYSTEMS)

Advantages	Disadvantages
Low installation costs	High component costs
Environmentally safe	Mechanical components – possibility of failure
Electrical power only required at vacuum station	Skilled design, installation and maintenance required
Always self-cleansing	Regular maintenance required
No possibility of vermin in pipelines	Standby facilities required
Possible water-saving technique if vacuum toilets used	Require area for situation of vacuum tanks and vacuum generation equipment
High water velocities prevent deposits in pipework	High-velocity water may cause transient plumbing noise
Minimal risk of leakage	
Can use small-diameter lightweight pipes that can be installed without a continuous fall	
Vertical lifts are possible	
Ability to easily separate greywater and black water	
High turnaround time – no need for cistern to refill for subsequent flushes	

TABLE 14.2 COMPARISON OF INSTALLATION AND OPERATION REQUIREMENTS OF DRAINAGE SYSTEMS

Parameter	Conventional (gravity)	Conventional (pumped)	Vacuum
Pipe size (mm)	Branches 32–100 Stacks 100–150	Branches 32–100 Stacks 100–150	Discharge from valves 32–50 Service connection 38–90
Pipeline gradient	To a fall	To a fall	Flexible arrangements, with minimal gradients or saw tooth profile. Vertical upward flow sections lifts can be used
Maintenance requirements	Negligible, only after abuse or blockage	Regular planned servicing of pumps and interface units	Regular, planned servicing of pumps and interface units
Energy requirements	At time of installation	At time of installation and throughout lifetime of building	At time of installation and throughout lifetime of building
Retrofit or extension of system within building	May be difficult to accommodate pipework and falls	May require additional pumps	Flexible layout makes installation simple
Conventional water consumption WCs	7.5 litre flush WC	7.5 litre flush WC	NA
Low water consumption WCs	6 litre flush WCs	6 litre flush WCs	1.5–3 litre flush vacuum toilets
Loading of sewerage system	Dependent upon appliances installed	Dependent on pumping rate	Discharge from forwarding pumps can be timed to coincide with low-flow periods

NA: not applicable.
Source: BRE 2001 (p. 3).

- in penal installations where isolation and control of the appliances is necessary to prevent concealment of weapons and drugs;
- unstable soil or flat terrain;
- where a high water table exists;
- in hospitals, hotels, office buildings or other areas where congested usage occurs, and flexibility in pipe routing is required to drain appliances;
- restricted construction conditions;
- building refurbishment.

When conventional gravity drainage systems are extended, as in refurbishment work, the existing gravity drainage system can be fed into the vacuum drainage system. This may be achieved by the use of a sump into which the wastewater from the gravity system drains. When sufficient water has accumulated in the sump, an interface valve will open allowing the wastewater to enter the vacuum drainage system. This arrangement can also be used to collect rainwater or as an interface between a building with conventional drainage and a vacuum sewer.

The collection arrangements and the small-bore pipework of vacuum drainage systems provide the possibility of easily separating greywater and black water. This would be of particular advantage if sewerage capacity was limited, as the greywater could be run to a watercourse after appropriate treatment.

14.3 Hot water and other dual supply systems

Dual drinking-water supply systems are those in which two different grades of water are available in separate piping systems. An example is the provision of a tap at a sink supplying water directly from the incoming water service while all other fixtures are fed from a storage tank. In developed countries, the most common is a secondary system of piping carrying hot water to sink, washbasin and bath. Occasionally a water softener is installed to treat part of a domestic system, but apart from these cases dual drinking-water supply systems are rarely found within single dwellings. An approach to water conservation being introduced in some communities is to recycle greywater to an outside tap for irrigation uses. A principal concern of all dual systems is the assurance that no cross-connections have occurred during installation or repair.

14.3.1 Hot water systems

Correct installation of non-return devices will prevent hot water from entering the cold water system in the event of an interruption of pressure. Regulations controlling the delivery of hot water from a hot water vessel may require tempered or thermostatically controlled water in all ablution areas, aged persons' homes, hospitals, schools and other public places, and use of thermostatically controlled mixing valves is encouraged where practicable. The acceptable temperature of hot water systems at the tap should be determined in concert with public health officials. To avoid scalding, especially of children, and in hospitals

and aged persons' homes, lower temperatures may be necessary. On the other hand, growth of *Legionella* organisms is reduced at temperatures above 50 °C, and this is a particular concern in hospitals and other large buildings such as hotels (see sections 3.1.4 and 3.3.1) (IPHE 2005).

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, a steam coil or a heat exchange from a central heating or other system, and the temperature is normally controlled to within fairly narrow limits, 60 °C being an average temperature setting in some countries. 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. Water heaters for the supply of hot water should always be installed strictly in accordance with the manufacturer's written instructions.

For reasons of safety, the water heater must be fitted with a combination temperature and pressure relief safety valve at the top of the unit prior to the commissioning of a mains or high-pressure water heater. To achieve this, a pressure relief safety valve must be fitted in the inlet or cold drinking-water supply pipework. The temperature and pressure settings of the respective safety valves should be specified by the manufacturer in accordance with the design capabilities of the specified water heater. The pressure setting for the pressure relief valve should be lower than the pressure setting for the combination temperature and pressure relief valve so that as the water heats up in the storage vessel and expands, the additional or excess volume is gently expelled from the lower and colder section of the water heater through the pressure relief safety valve. Where the available drinking-water supply pressure exceeds the upper limits of the pressure relief safety valve it is necessary to install a pressure reduction valve, appropriate to the pressure ratings involved, immediately after the isolation valve to the water heater and before the non-return valve. In some cases, it may be preferable to lower the drinking-water supply pressure to the whole system to avoid pressure imbalance in the hot and cold drinking-water supply systems. In these cases, the pressure reduction valve could be installed in the cold drinking-water supply pipework before it enters the building.

Low-pressure water heaters must not be pressurized beyond normal localized atmospheric conditions within the operating parameters of the manufacturer's specification. Equalizing the drinking-water supply pressure in a particular fitting (such as a shower) with the whole system is a little more complicated but it can be done by taking off a dedicated cold water service line from the

drinking-water supply tank to the heater unit. Depending on the capacity of the cold water distribution system, a separate supply tank may be required to avoid depleting the dedicated cold drinking-water supply tank serving the hot water system. The hot water system that is not considered potable should never be allowed to enter the cold water cistern (see section 12.2).

14.3.2 Other dual supply systems

Multiple dwellings and multi-storey buildings may have fire protection systems such as sprinkler variety systems or high-pressure mains and hydrants. Industrial and commercial establishments may have one or more systems of piping. These may carry cooling or process water from a secondary source or mains water that has been specially treated for the purpose.

When one component of the dual system has been derived from another source, or when it carries mains water that has been treated, heated or stored, it is essential that the non-mains component is not allowed to reconnect with the mains water. Drinking-water supply systems should be designed, installed and maintained so as to prevent contaminants from being introduced into the drinking-water supply system. Water of drinking-water quality should be supplied to plumbing fixtures or outlets for human consumption, bathing, food preparation and utensil or clothes washing. Where water supplied from one source is connected to another water source, an appropriate backflow prevention device should be fitted and the installation should be registered with the water supplier.

Systems that permit the introduction of any foreign substance into the water service should not be connected directly or indirectly to any part of the drinking-water supply system. This includes systems for fire protection, garden watering and irrigation, or any temporary attachment to the water service. This can only be done with backflow prevention and cross-connection control devices.

Combined tanks storing potable water alongside water for other purposes should have a double partition wall installed internally to separate the two supplies. The space between the partition walls should be arranged to ensure that any leakage cannot enter the other compartment of the tank. To achieve this, an external drainage point should be provided from the bottom of the void or space so that any discharge or leak is readily noticed.

14.4 Water storage vessels

Separate water storage vessels are an integral part of many dual supply systems. This section deals with requirements for the storage of water supplied from the water main or other drinking-water sources. In the design of these systems, it is important to ensure that the required air gap is established between the drinking-water supply inlet and the overflow spill level of the fixture.

Water storage tanks are appropriate for use in the following circumstances:

- sanitary flushing
- supply of drinking-water
- firefighting
- air-conditioning
- refrigeration
- ablutions
- prevention of cross-connections
- make-up water
- contingency reserve.

Requirements relating to installation and protection of water storage tanks:

- Tanks must be installed on bases, platforms or supports designed to bear the weight of the tank when it is filled to maximum capacity, without undue distortion taking place.
- Metal tanks (and other tanks when similarly specified) should be installed with a membrane of non-corrosive insulating material between the support and the underside of the tank.
- Tanks must be supported in such a manner that no load is transmitted to any of the attached pipes.
- Tanks must be accessible for inspection, repairs, maintenance and replacement.
- Tanks must be provided with a cover, designed to prevent the entry of dust, roof water, surface water, groundwater, birds, animals or insects.
- Insulation from heat and cold should also be provided.
- Tanks storing potable water should not be located directly beneath any sanitary plumbing or any other pipes conveying non-potable water.

Requirements relating to access to water storage tanks:

- Adequate headroom and side access must be provided to enable inspection, cleaning and maintenance of the interior and exterior of the tank.
- Where the interior depth of any storage tank exceeds 2 metres, access ladders of standard design should be installed and entry safety codes complied with.

Requirements relating to materials used in water storage tanks:

- The internal surfaces of tanks should be coated with a protective coating approved for drinking-water contact applied in accordance with the manufacturer's instructions if the tank is to supply drinking-water.
- Storage cylinders should be made of non-corrosive material.
- Tanks, pipes, heating coils and related fittings 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 the tank and piping, it should always be heavily galvanized.

14.5 Labelling and colour coding of non-drinking-water supply systems

Where the alternative supply is a non-potable drinking-water supply, it needs to be clearly and permanently labelled "Caution – not for drinking" at every outlet. Exposed piping must be identified by colour coding (lilac) and permanent markings or labelling. The use of the lilac (light purple) colour on pipes and outlet points has been adopted in some countries to warn that the contents being conveyed within are not for drinking purposes. In the United Kingdom greywater colours are green-black-green, and reclaimed water pipe colours are green-black-green with an additional white band in the centre.

Where the non-potable alternative supply is installed below ground, the service should have a continuous marker tape stating that the pipe below is a "Non-potable drinking-water supply – not for drinking". The marker tape should be installed in the trench immediately above the service. Where piping conveys water downstream from a high or medium hazard, the backflow prevention device shall be clearly and permanently labelled "Caution – not for drinking" along its length. To further assist in identification, outlet points or taps should be painted or coated lilac and a label or sign should be fixed or erected immediately adjacent stating "Caution – not for drinking".

The level of potential cross-connection hazard rating should be classified by use of a method that allows easy identification of the risk level. A commonly used approach is to classify the contained fluids according to levels of risk from 1 (no risk or minimal risk) to 5 (highest risk).

Fluid category 1. Drinking-water supplied by the authority and complying with the plumbing code of practice.

Fluid category 2. Water in fluid category 1 whose aesthetic quality is impaired due to change in temperature or the presence of substances or organisms causing a change in taste, odour or appearance. This includes water in a hot water distribution system.

Fluid category 3. Fluid that represents a slight health hazard because of the concentration of substances of low toxicity. This includes any fluid that contains copper sulfate solution or similar chemical additives and sodium hypochlorite (as found in chlorine and common disinfectants).

Fluid category 4. Fluid that represents a significant health hazard because of the concentration of toxic substances. This includes any fluid that contains chemical or carcinogenic substances or pesticides (including insecticides and herbicides) and organisms that pose a potential risk to health at concentrations sufficiently above drinking-water standards or guidelines.

Fluid category 5. Fluid that represents a serious health hazard because of the concentration of pathogenic organisms or radioactive or very toxic substances.

This includes any fluid that contains faecal material or other human waste, butchery or other animal waste, or pathogens from any other source.

14.6 Situations where there is a risk of cross-connection

There are recognized risks of cross-connection in agricultural and horticultural properties, catering and allied trade installations, domestic installations, health and sanitary service installations, and in industrial and commercial installations. The level of protection required should be determined by identifying the hazards within the premises, then working upstream from each hazard. The water must be regarded as non-potable until a backflow prevention device is provided suitable to the degree of the rated hazard. If a cross-connection has been detected, the pipe system should be taken out of service, flushed, cleaned and disinfected, and the water tested and determined to be safe before it is put back into service. When assessing a potential backfIow condition, consideration must be given to the complexity of piping, the possibility that the piping configuration has been altered and the possibility that negligent or incorrect use of equipment has resulted in a backflow condition. The following summarizes the main risks in each of these situations.

14.6.1 Agricultural and horticultural properties

In market gardens, poultry farms and dairy farms there is a risk of cross-connection between the water service and dam water, drinking nipples, fogging sprays, irrigation pipes, antibiotic injectors, cleansing injectors, vertical sprays for vehicle washing or any submerged outlet or hose at tanks or feed troughs.

14.6.2 Catering and allied trade installations

In commercial kitchens, hotels and clubs there is a risk of cross-connection between the water service and water-cooled refrigerant units containing methyl chloride gas or any submerged outlets or hoses that connect to glasswashers and dishwashers, bains-marie, food waste disposal units, garbage can washers, ice-making machines or refrigerators, or hoses supplying water to sinks or other receptacles.

14.6.3 Domestic installations

In domestic installations, there is a risk of cross-connection of the water service to a haemodialysis machine, bidet, water-operated venturi-type ejectors attached to garden hoses when used to empty or clean out wastewater pits, septic tanks, gullies or trenches, storm water sumps, domestic grease traps, or any submerged outlets, or discharge point of the water service in sanitary flushing cisterns, garden hoses supplying water to swimming pools, ornamental ponds, fish ponds, hose taps below the flood level rim of any fixture, or located below ground surface level.

14.6.4 Health and sanitary service installations

These installations include the following risks of cross-connection:

- council sanitary depots: cross-connection between the water service and sanitary pan washers, truck washers and pan-dumping machines;
- dental surgeries: any submerged outlets of the water service connected to chair bowls and venturi-type water aspirators;
- funeral parlours: in embalming areas, the cross-connection between the water service and water-operated aspirator pumps;
- hospitals and nursing homes: submerged outlets of the water service at bed pan washers, bed bottle washers, sterilizers, steam autoclaves, instrument washers, and any cross-connection between the water service and steam pipes, steam boilers or steam calorifiers;
- mortuaries: postmortem areas, submerged water service outlets at autopsy tables, flushing rim floor gullies or trenches, specimen tables and instrument-washing sinks.

14.6.5 Industrial and commercial installations

A common site of cross-connection relates to the use of tanks. Any submerged discharge point of hoses or pipes that supply water to rinse tanks, process tanks and other tanks may pose a cross-connection risk. The industries and commercial installations that carry a risk of cross-connection in these installations include the following:

- abattoirs: cross-connection between the water service and steam pipes, steam boilers or steam calorifiers, and the washing sprays in contact with animal carcasses;
- bleaching works: cross-connection between the water service and steam pipes, steam boilers, steam calorifiers, or any submerged outlets at revolving drum washers, or any pipes conveying non-potable water;
- breweries and cordial and soft drink plants: cross-connection between the water service and the contents of gas cylinders, steam pipes, steam boilers or steam calorifiers, or any submerged water service outlets at drum washers, bottle washers or process tanks;
- butcher shops: cross-connection between the water service and any water-cooled refrigerant units containing methyl chloride gas, or water-powered food-processing machines;
- chemical plants: cross-connection between the water service and chemical pipelines, or the submerged water service pipe outlets at drum washers and process tanks;
- dry cleaners: cross-connection between the water service and solvent stills;
- dyeing works: cross-connection between the water service pipes and steam

pipes, foul water inlet sprays in process tanks, and any submerged water service pipe outlets at vats, tanks and colanders;

- engineering works: cross-connection between the water service and any steam boilers, diesel oil recirculating systems, recirculated cooling water for machines, testing pressure vessels, oil-cooling coils, pump priming, compressed air pipelines and venturi-type ejectors in vehicle maintenance pits;
- laboratories: cross-connection between the water service and any aspirator pumps, fume cupboards, stills, centrifuges, blood-testing machines, air scrubbers, test-tube-washing machines, animal feeding troughs, and high-pressure gas cylinders;
- laundries: cross-connection between the water service and any clothes-washing machines, starch tanks, soap-mixing vats, and recirculated hot water tanks;
- milk-processing plants: cross-connection between the water service and any steam pipes, steam boilers, steam calorifiers, or any submerged outlets at bottle-washing machines, milk can-washing machines, and process chilling tanks;
- oil storage depots: cross-connection between the water service and foam firefighting equipment;
- poultry-processing plants: cross-connection between the water service and any steam pipes, steam boilers, steam calorifiers, or any submerged outlets at feather-plucking machines, carcass-washing machines, offal boilers and process tanks;
- photographic developers: cross-connection between the water service and X-ray equipment, or any submerged outlets at tanks and rinse machines;
- plating workings: cross-connection between the water service and solvent, acid or alkali tanks, cooling coils, steam pipes, or any submerged outlets at tanks and rinse machines;
- tanneries: cross-connection between the water service and vats, drum process tanks or steam pipes;
- wool processors: cross-connection between the water service and lanolin centrifuges and head recycling coils, or any submerged outlets or hoses at vats, drums and tanks.

14.7 Fixture unit calculations for multiple dwellings

The fixture unit concept is a method of calculating drinking-water supply and drainage piping requirements within large buildings where 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 when all other fixtures in the building are being operated at the same time. In practice, the chances of their simultaneous use are remote and the piping design criteria may be relaxed to some degree.

A fixture unit (f/u) value is assigned to each type of fixture based on its rate of water consumption, on the length of time 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 14.3. 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 order of 0.6 to 0.7, but depending upon the margin of simultaneous use protection necessary under local conditions (Taylor & Wood 1982).

The total number of fixture units connected to each branch pipe is then added, multiplied by the factor referred to above, and the result used to calculate the flow in water or drainage pipes in accordance with tables such as the following 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.

TABLE 14.3 FIXTURE UNIT VALUES FOR SOME COMMON PLUMBING FIXTURES

Fixture	Fixture units
Bath or shower	2
Bidet	2
Clothes washer (automatic)	3
Drinking fountain	3
Kitchen sink	1.5
Urinal or water closet (with flush tank)	3
Urinal or water closet (with flush valve)	6
Washbasin	1

Source: Taylor & Wood 1982 (p. 153).

From Table 14.4 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 (such as in baths and sinks) should be assumed to take equal quantities of each for design purposes: a bath would be counted as one fixture unit on the cold water system, and one fixture unit on the hot water. Supply piping would be calculated accordingly, while the total figure of two fixture units would be used to design the drainage piping.

From Table 14.5 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 millimetres (4 inches) diameter, and that no internal branch or drain of less than 80 millimetres (3 inches) diameter should carry the discharge of more than two water closets.

An alternative to the fixture unit method for calculating flows is used in some French-speaking countries. This method assigns individual flow values to each

TABLE 14.4 PEAK WATER DEMAND OF PLUMBING FIXTURES

No. of fixture units	litres per second	US gallons per minute	UK gallons per minute
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

Source: Taylor & Wood 1982 (p. 153).

TABLE 14.5 MAXIMUM LOADS FOR HORIZONTAL FIXTURE BRANCHES AND BUILDING DRAINS OR SEWERS

Diameter of drainpipe		Fixture branch	Building drain or sewer			
mm	inches	Min. slope 2% (1 in 50) f/u[a]	Slope 0.5% (1 in 200) f/u[a]	Slope 1% (1 in 100) f/u[a]	Slope 2% (1 in 50) f/u[a]	Slope 4% (1 in 25) f/u[a]
32	1.25	1	—	—	—	—
40	1.5	3	—	—	—	—
50	2	6	—	—	—	26
65	2.5	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

[a] f/u = fixture units.
Source: Taylor & Wood 1982 (p. 154).

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.