# 6 Hot- and cold-water supplies

**Learning objectives**

Study of this chapter will enable the reader to:

1. recognize the quality of water supplied to buildings;
2. explain pH value;
3. explain water hardness;
4. identify and apply appropriate water treatment methods;
5. decide appropriate applications for mains pressure and storage tank cold- and hot-water systems;
6. understand pressure-boosted systems for tall buildings;
7. apply economic instantaneous and storage techniques for hot-water provision;
8. understand primary and secondary pipe circulation systems;
9. calculate the heater power for hot-water devices;
10. understand demand units;
11. understand how cold- and hot-water pipe systems are designed;
12. be capable of carrying out basic cold- and hot-water pipe-sizing calculations;
13. understand pipe equivalent length;
14. understand pipe pressure loss calculation;
15. use CIBSE pipe-sizing data;
16. allocate sanitary appliances appropriate to building usage;
17. discuss the use of pipe materials and their methods of jointing;
18. have a basic understanding of how solar energy can be utilized in the provision of hot water in buildings.

**Key terms and concepts**

acidic and alkaline water 179; base exchange 180; centralized hot-water system 183; concentrating solar collector 198; corrosion 179; decentralized hot-water system 184; delayed-action ball valve 183; demand units 187; demineralization 180; dezincification 179; direct mains water 181; electrolytic action 195; equivalent length 188; flat-plate solar collector

## Introduction

The convenience of piped water systems is likely to be taken for granted by those who have not been camping or caravanning. The provision of safe and hygienic water supplies is of paramount importance, and a considerable amount of engineering is involved in such provision.

The basics of water treatment are outlined, and then the ways in which water is distributed throughout buildings are discussed. The flows of water to sanitary appliances depend upon their frequency of use, which is not accurately predictable. The concept of pipe sizing with demand units leads to design calculations of water networks.

Calculation of the likely number of sanitary fittings to be installed is demonstrated. Water system materials and the application of solar heating are explained.

## Water treatment

About 10% of the rainfall in the UK is used in piped services. Storage in reservoirs allows sedimentation of particulate matter, and then the water is filtered through sand and injected with chlorine for sterilization. A slow sand filter consists of a large horizontal bed of sand or a sand and granulated activated carbon sandwich. The carbon comes from coal and acts as a very efficient filter that traps microscopic traces of pesticides and herbicides. Water percolates down through the bed by gravity. Rapid sand filters have the raw water pumped through a pressurized cylinder that contains the filter medium. This filter material is either crushed silica, quartz or anthracite coal. Filtering removes metallic salts, bacteria and turbidity (muddiness). It also removes colouring effects, odours and particles, which affect the taste of the water. The naturally occurring pH value and the total dissolved salt concentration are virtually unaltered by the water supply authority.

Water quality varies with the local geology and can be classified as hard, soft, acidic or alkaline. Mineral salts of calcium and magnesium have soap-destroying properties and are considered in the evaluation of water hardness.

Temporary hardness is due to the presence of calcium carbonate, calcium bicarbonate and magnesium bicarbonate, which dissolve in water as it passes through chalky soil. These salts are deposited as scale on heat transfer surfaces during boiling, causing serious reduction in plant efficiency. They are known as carbonate hardness.

Permanent hardness is due to the presence of the non-carbonate salts calcium sulphate, calcium chloride, magnesium chloride and other sulphates and chlorides. Neutralization of these is achieved by means of chemical reactions.

Soft water contains up to 100 mg/l of hardness salts, as in Cornwall, and hard water contains as much as 600 mg/l, as in parts of Leicestershire. Acidic water is produced by contact with decomposing organic matter in peaty localities and normally occurs in soft-water regions. This water is very corrosive to steel, is plumbo-solvent and can cause dezincification of gunmetal pipe fittings.
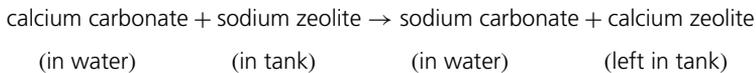
The pH value denotes acidity or alkalinity due to the presence of free hydrogen ions in the water: acidic water, pH < 7; neutral water, pH = 7; alkaline water, pH > 7. Copper and plastic pipes and fittings can be used in acidic water regions. Hard-water areas are generally alkaline.

Water treatment for large boiler plants includes chemical injection to reduce corrosion from dissolved oxygen, and the pH value is raised to 11. Galvanized metal can be used where the pH value is 7.4 if the carbonate hardness is greater than 150 mg/l.

Users of large amounts of water may have treatment plant that removes or converts hardness salts to less harmful salts.

**Base exchange**

Raw water from the mains passes through a tank of zeolite chemicals where a base exchange takes place:

calcium carbonate + sodium zeolite → sodium carbonate + calcium zeolite

   (in water)       (in tank)       (in water)       (left in tank)

Similar base exchanges occur between the zeolites and other hardness salts in the raw water, turning them into non-scale-forming salts. On complete conversion of all the sodium zeolite, the filter bed is backwashed with brine (sodium chloride solution) which undergoes exchange with the calcium zeolite.

calcium zeolite + sodium chloride → sodium zeolite + calcium chloride

   (in tank)      (in flush water)      (in tank)      (flushed to drain)
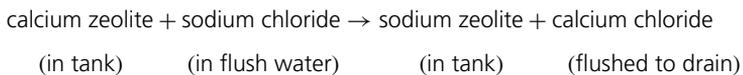
The normal flow direction can then be resumed. The running cost of the system is limited to consumption of common salt, a small pump, periodic replacement of the zeolites and a small amount of maintenance work.

Steam boilers accumulate the salts passing through the treatment plant, and if they were allowed to become too numerous they would be carried over into the steam pipes and clog safety valves and pressure controllers. Either continuous or intermittent blow-down of boiler water to the drain is designed to control salt concentration. The high-pressure blow-down water is cooled before being discharged into the drains, and the heat is recycled.

*Demineralization*

Complete removal of mineral salts is very expensive, but it is essential for power station steam boilers, high-performance marine boilers and some manufacturing processes, where the presence of impurities is unacceptable. Raw water is passed through chemical filters in several stages to complete the cycle.

*Reverse osmosis*

Reverse osmosis is a filtration technique in which untreated water is pumped alongside a semi-permeable membrane in a pipe system. Clean water passes through the membrane. This method is used to produce drinking water in desert regions.

*Solar distillation*

Solar stills consist of glass-covered water troughs in which solar radiation evaporates the water, which then condenses on the cooler sloping glass roof and is collected in channels. This method can be used in hot locations.

### Cold-water services

Mains water is used in two ways: direct from the main and as low-pressure supplies from cold-water storage tanks.

### *Mains supplies*

At least one tap per dwelling and taps at suitable locations throughout large buildings are connected to the main for drinking water. The main also supplies ball valves on cold-water storage tanks and machines requiring a high-pressure inlet.

The economical use of water is important for safety, environmental and cost control reasons. The manual flush control of WCs and the tap operation of other appliances allows responsible usage. Urinals present a particular hygiene and water consumption contradiction. The user has no control over the flushing of water through the trough or bowl. The absence of flushing water leaves the urinal unpleasantly odorous and discoloured. Cleaning staff may counteract this by the excess dumping of deodorant blocks into the urinal. Perfumed toilet blocks are up to 100% para dichlorobenzene. Toilet-cleaning fluid contains phosphoric acid. These toxic chemicals are passed to the sewage treatment plant through the drain system. Uncontrolled flushing when the urinals remain unused, particularly overnight, results in wasteful water consumption and no benefit to the user. In the UK the supply of potable water plus the removal of waste water from consumers may cost around £1.50 per $m^3$ from a meter on the supply inlet pipe. An uncontrolled urinal cistern of 9 litre would flush, say, four times per hour, 24 h per day for 365 days in a year and consume 315 $m^3$ of water costing up to £500.

The installation of a water inlet flow control valve to a range of urinals will only allow flushing when appliances have been used, saving consumption. The valve may be operated from a passive infrared presence detector, discharge water temperature sensor or a variation in the water pressure within the same room. A short-term water flow to a WC or basin causes the stored water pressure within bellows to exceed the pressure in the pipeline. A diaphragm opens and allows water to flow to the urinal cistern until the accumulator pressure again equals the pipeline pressure; water flow can be adjusted to avoid wastage.

### *Low-pressure supplies*

Static water pressures in tall buildings are reduced by storing water at various levels. Sealed storage tanks are used for drinking water. Open water tanks become contaminated with airborne bacteria and are only used for sanitary purposes. Cold-water services are taken to taps, WC ball valves, hot-water storage cylinders and equipment needing low-pressure supplies. A separate cold feed is taken to a shower or group of showers to avoid the possibility of scalding. Tanks are sized to store the total cold-water requirement for a 24-h period.

The minimum mains water pressure available in the street is 100 kPa (1 bar), which is 1 atmosphere gauge or 10 m height of water. The water supplier may be able to provide 300 kPa, or enough pressure to lift water to the top of a building 30 m high; however, allowance has to be made for friction losses in pipelines and discharge velocity, which effectively limits the vertical distance to between 2 and 6 storeys.

Separation of the contaminated water being used within the building for washing, flushing sanitary appliances, circulating within heating and air-conditioning cooling systems, evaporative cooling towers, ornamental fountains, agricultural irrigation or manufacturing processes from

potable mains water is achieved by using the following:

1.  a storage tank with ball valve (break tank);
2.  a permanent air gap between the tap discharge and the contaminated water level (e.g. wash basin);
3.  a single-seat non-return valve (check valve);
4.  a double-seat check valve.

The Water Byelaws 1989 classify the risk of contamination from the building reaching upstream into the water main in three groups, each having its own protection (Table 6.1).

Cold-water storage tanks are expected to contain water of similar quality to that supplied from the main and so must be covered to exclude foreign matter, insects and light as well as being thermally insulated and not contaminating the stored water themselves. Tanks are generally not larger than 2 m long by 1 m wide by 1 m high, and pipe connections must ensure that water flushes through all of them to eliminate stagnation.

Servicing or isolating valves are located on the inlet to all ball valves on storage tanks and WC cisterns to facilitate maintenance without unnecessary water loss or inconvenience to the occupier. A servicing valve is required on all outlets from tanks of more than 15 l, that is, larger than a WC cistern.

The drinking and food-rinsing water tap at a kitchen sink must be connected to the water main before any water softener enters and a check valve is required between this tap and the softener.

Service entry into a building is via an underground pipe passing through a drain pipe sleeve through the foundations and rising in a location away from possible frost damage. An external stop tap near the boundary of the property is accessible from a brick or concrete pit. A ground cover of 760 mm is maintained over the pipe. A stop valve and drain tap are fitted to the main on entry to the building to enable the system to be emptied if the building is to be unoccupied during cold weather.

A water meter is the next pipe fitting. This has a rotary flow sensor, which is used to integrate the quantity of water that has passed. The cubic metres of water that are supplied, and charged for, are assumed to be discharged into the sewer. A separate charge is levied for the supply of potable water and for the acceptance of the contaminated discharge foul water. The consumer normally has no choice but to pay both the charges.

In tall buildings the pressure required to reach the upper floors can be greater than the available head, or pressure, in the mains. A pneumatic water-pressure-boosting system is used as shown

Table 6.1 Classification of contamination risks.

| Class | Risk | Example of risk class | Type of protection |
|---|---|---|---|
| 1 | Serious danger to life | WC, bidet, urinal, agricultural or industrial process | Permanent air gap or break tank |
| 2 | May cause minor illness | Clothes, dishwashing and drinks vending machines, commercial water softeners | Permanent air gap, break tank or double check valve |
| 3 | May cause an unpleasant taste, odour or discolouration | Single outlet mixer taps and domestic water softeners | Any class 1 or 2 protection or a single check valve |
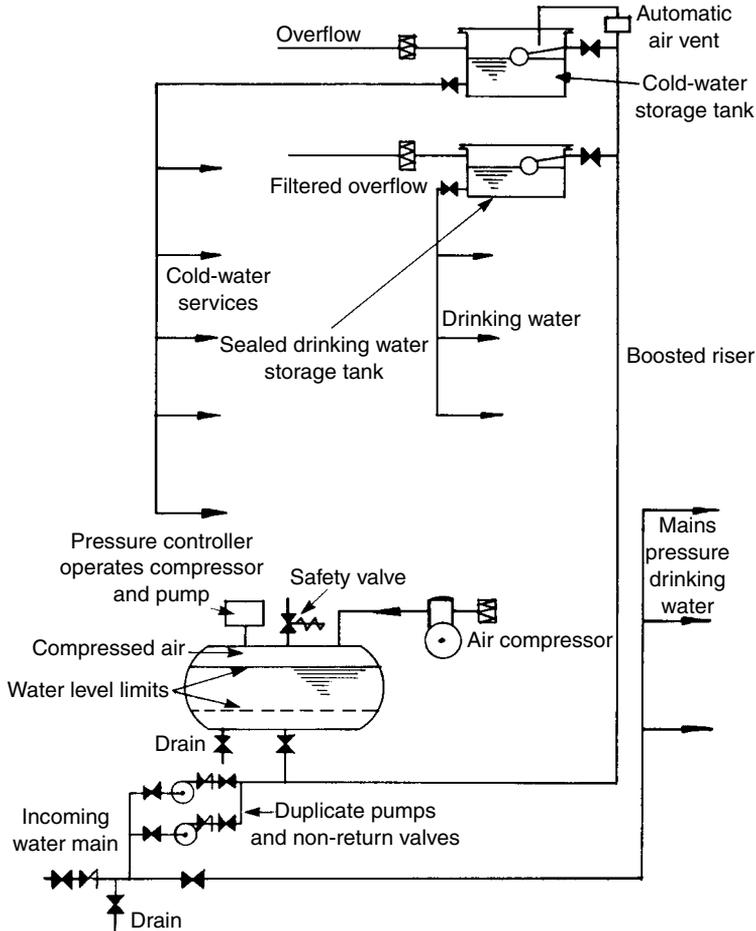
6.1  Pneumatic water-pressure-boosting system for tall buildings.

in Fig. 6.1. Float switches in the storage tanks operate the pump to refill the system and minimize running times to reduce power consumption. A delayed-action ball valve on the cold-water storage tanks can be used. This delays the opening of the ball valve until the stored water has fallen to its low-level limit. System pressure is maintained by a small air compressor and pneumatic cylinder. The controller relieves excess pressure and switches on the compressor when the air pressure falls. During much of the day, water is lifted pneumatically at much lower cost than if it were pumped.

Cold-water storage to cover a 24-h interruption of supply (CIBSE, 1986) ranges from 45 l/person for offices to 90 l/person for dwellings and 135 l/person for hotels.

### Hot-water services

Hot water can either be generated by the central boiler plant and stored, or produced close to the point of use by a more expensive fuel.

### Central hot-water storage

The low-cost fuel used for the central heating plant is also used for the hot-water services boiler. This is located within the main boiler house and a large volume storage cylinder is employed. A small power input boiler is run almost continuously, winter and summer, under thermostatic control from the stored hot water. Primary circulation pipes are kept short and well-insulated.

This system can meet sudden large demands for hot water. Secondary circulation pipes distribute hot water to sanitary appliances. A pump is fitted in the secondary return; its function is to circulate hot water when the taps are shut and it does not appreciably assist draw-off rates from taps. Connections from the secondary flow to the tap are known as dead-legs and are limited to 5 m of 15 mm diameter pipe. This minimizes wastage of cold water in the non-circulating pipework when running a tap and waiting for hot water to arrive.

### Decentralized system

The decentralized system is mainly for small hot-water service loads distributed over a large building or site where it would be uneconomic to use a central storage cylinder and extensive secondary pipework. Electricity or gas can be used in small storage or instantaneous water heaters located at the point of use. They are connected directly to the water main. Figures 6.2 and 6.3 show the operational features of gas-fired instantaneous and storage water heaters.

Mains-connected storage water heaters are protected from excess pressure and water temperature by a combined safety valve such as that shown in Fig. 6.4. On rise of mains water pressure, an internal spring relieves water to outdoors through the female-screwed pipe connection. On rise of water temperature within the stored volume, the wax thermal probe expands to open the relief valve. Manual testing of the spring valve during routine inspections is done by raising the lever to discharge water. When testing like this, collected debris from corrosion of the water
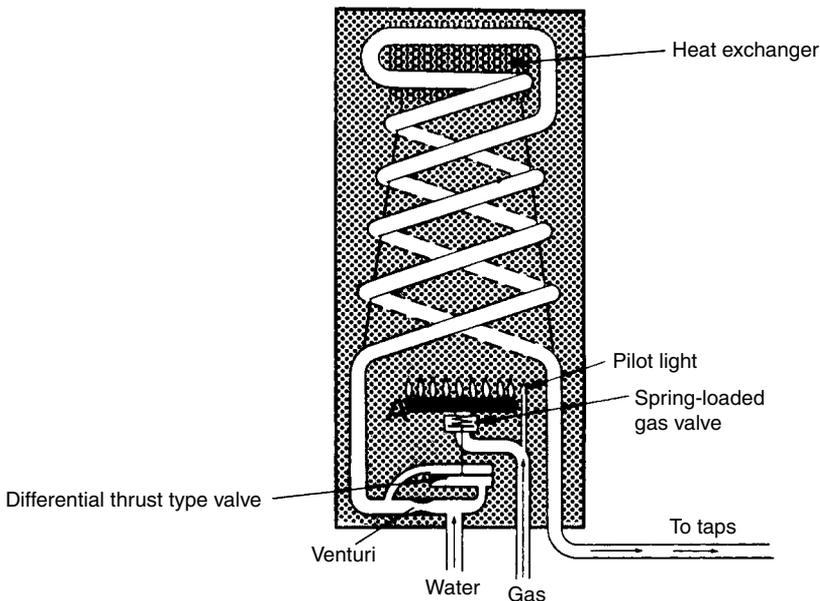


6.2  Gas-fired instantaneous water heater.
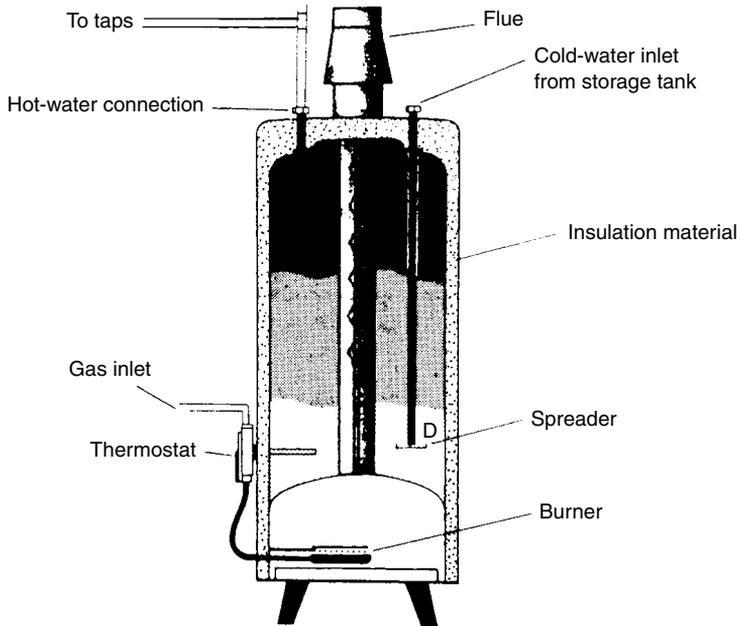
6.3  Gas-fired storage water heater.



6.4  Mains water pressure safety valve.

storage tank or salt encrustation often causes the spring-controlled valve to remain cracked open and leak water, resulting in a valve replacement task.

Electric instantaneous heaters have power consumptions of up to 6 kW and produce water at 40°C and up to 3 l/min at 100% efficiency. Small electric storage heaters of 7 l are fitted over basins or sinks. Capacities of up to 540 l operate on the off-peak storage principle. Immersion heaters are controlled by time switches and thermostats and are connected in 3 kW stages.

### The indirect hot-water system

The basic layout of the combined central heating and indirect hot-water service system is shown in Fig. 6.5. The cylinder is insulated with 75 mm fibre glass and should have a thermostat attached to its surface at the level of the primary return. Water is stored at 65°C, and when fully charged the thermostat closes the motorized valve on the primary return. This 'off' signal may also be linked into the pump and boiler control scheme to complete the shut-down when the central heating controls are satisfied.

Hot-water pipes are insulated with a minimum of 25 mm of insulation, as are tanks exposed to frost. The primary system feed and expansion tank has a minimum capacity of 50 l, and the cold-water storage tank has a capacity of at least 230 l.

Hot-water storage requirements at 65°C are as follows: office, 5 l/person; dwelling, 30 l/person; hotel and sports pavilion, 35 l/person (CIBSE, 1986).
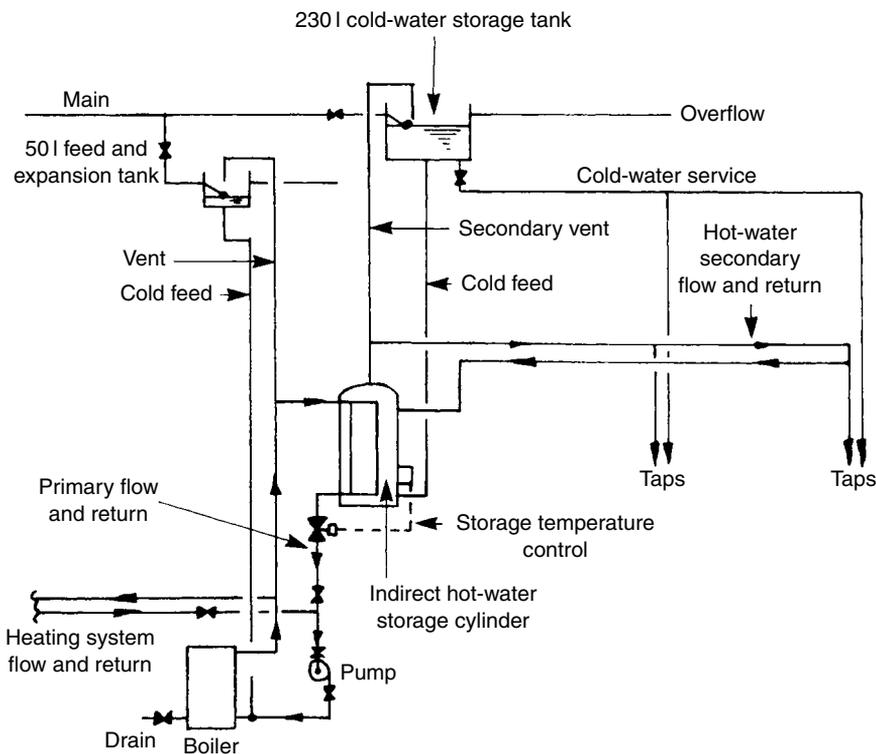


6.5  Indirect hot-water storage system.

**EXAMPLE 6.1**

A dwelling has a 135 l hot-water storage indirect cylinder. The stored cold-water temperature is 10°C and the hot water is to be at 65°C. Calculate the necessary heat input rate to provide a 3-h recovery period from cold.

$$\text{Heat input rate} = \frac{\text{mass kg}}{\text{time h}} \times SHC \; \frac{\text{kJ}}{\text{kgK}} \times \text{temperature rise K}$$

$$= \frac{135 \; l}{3 \; h} \times \frac{1 \; \text{kg}}{1 \; l} \times 4.19 \; \frac{\text{kJ}}{\text{kgK}} \times (65 - 10) \; \text{K}$$

$$= \frac{135}{3} \times 4.19 \times (65 - 10) \; \frac{\text{kJ}}{\text{h}} \times \frac{1 \; h}{3600 \; s} \times \frac{\text{kWs}}{\text{kJ}}$$

$$= 2.881 \; \text{kW}$$

This can be rounded to 3 kW to allow for heat losses and is adequate for most dwellings with two to four occupants.

**Pipe sizing**

The demand for water at sanitary appliances is intermittent and mainly random but has distinct peaks at fairly regular times. The pipe sizes for maximum possible peak flows would be uneconomic. Few appliances are filled or flushed simultaneously. To enable designers to produce pipe systems that adequately match likely simultaneous water flows, demand units (*DU*) are used.

   *DU* are dimensionless numbers relating to fluid flow rate, tap discharge time and the time interval between usage.

   They are based on a domestic basin cold tap water flow rate of 0.15 l/s for a duration of 30 s and an interval between use of 300 s. This application is given a theoretical *DU* of 1.0 and other appliances are given relative values. Table 6.2 lists practical *DU*s.

   The use of spray taps and small shower nozzles greatly reduces water consumption. Design water flow rates of 0.05 l/s for a spray tap, 0.1 l/s for a shower spray nozzle over a bath and 0.003 1/s per urinal stall can be used in place of *DU*. Figure 6.6 (CIBSE, 1986) is used to convert *DU* into water flow rates.

   The design procedure for pipe sizing is as follows.

1.  Draw the pipework layout on the building plans.
2.  Mark the *DU* appropriate to each sanitary fitting on the drawing.

Table 6.2  Practical demand units (*DU*).

| Fitting | Application | | |
|---|---|---|---|
| | *Congested* | *Public* | *Private* |
| Basin | 10 | 5 | 3 |
| Bath | 47 | 25 | 12 |
| Sink | 43 | 22 | 11 |
| WC (13.5 l cistern) | 35 | 15 | 8 |
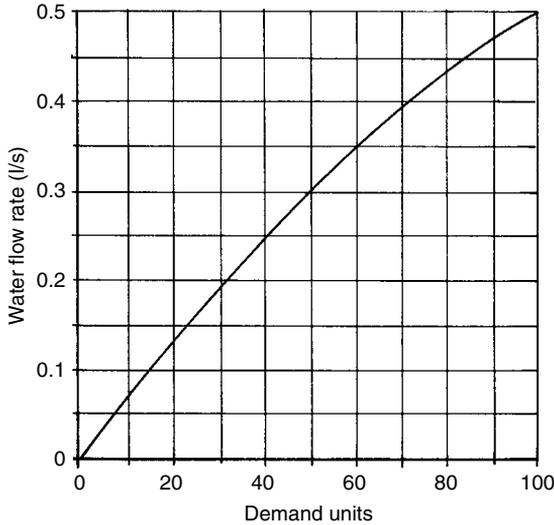
6.6  Simultaneous flow data for water draw-off points.

Table 6.3  Flow of water in copper tube of various diameters.

| $\Delta p/EL$ (N/m³) | Water flow rate q (kg/s) | | | | |
|---|---|---|---|---|---|
| | 15mm | 22mm | 28mm | 35mm | 42mm |
| 1000 | 0.160 | 0.429 | 0.933 | 1.60 | 2.58 |
| 1500  $v = 1.5$ | 0.201 | 0.537 | 1.170 | 2.00 | 3.22  $v = 3$ |
| 2000 | 0.236 | 0.630 | 1.370 | 2.34 | 3.77 |
| 2500  $v = 2$ | 0.268 | 0.712 | 1.540 | 2.65 | 4.26 |
| 3000 | 0.296 | 0.787 | 1.710 | 2.92 | 4.70  $v = 4$ |

Note:  $v$ = water velocity (m/s).

Source: Reproduced from *CIBSE Guide* (CIBSE, 1986) by permission of the Chartered Institution of Building Services Engineers.

3.  Sum all the *DU* along the pipework to the water source, which will be the storage tank or incoming water main.
4.  Convert *DU* to water flow rates using Fig. 6.6.
5.  Find the head of water *H* (in metres) causing the flow to each floor level.
6.  Estimate the equivalent length (*EL*) of the pipe run to each floor in metres. This can be taken as the measured length plus 30% for the frictional resistance of bends, tees and the tap.
7.  Find the index circuit. This is the circuit with the lowest ratio of *H* to *EL*.
8.  Choose pipe sizes from Table 6.3 for the index circuit.
9.  Determine the other pipe sizes from the *H/EL* figure appropriate to each branch of the index circuit.
10.  Determine the water flow rate and head for a bronze-body hot-water service secondary pump, if one is required.

A notation system can be adopted to gather pipe-sizing data together on drawings, as shown in Fig. 6.7.
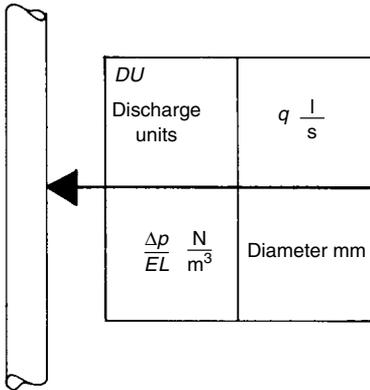
6.7  Notation for pipe-sizing data on drawings.

**EXAMPLE 6.2**

A domestic cold-water service system is shown in Fig. 6.8. The water main in the street is 50 m from the entry point shown and the supply authority provides a minimum static pressure of 20 m water gauge. The velocity energy and the frictional resistance at the ball valve amount to 2 m water gauge. Determine the pipe sizes.



50 m to water main
Water main head = 20 m
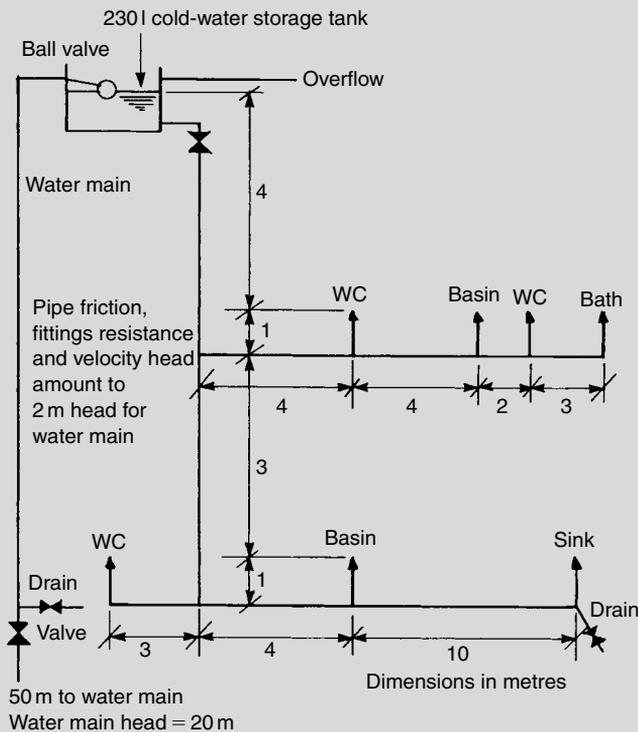
6.8  Cold-water service pipe-sizing diagram for Example 6.2.
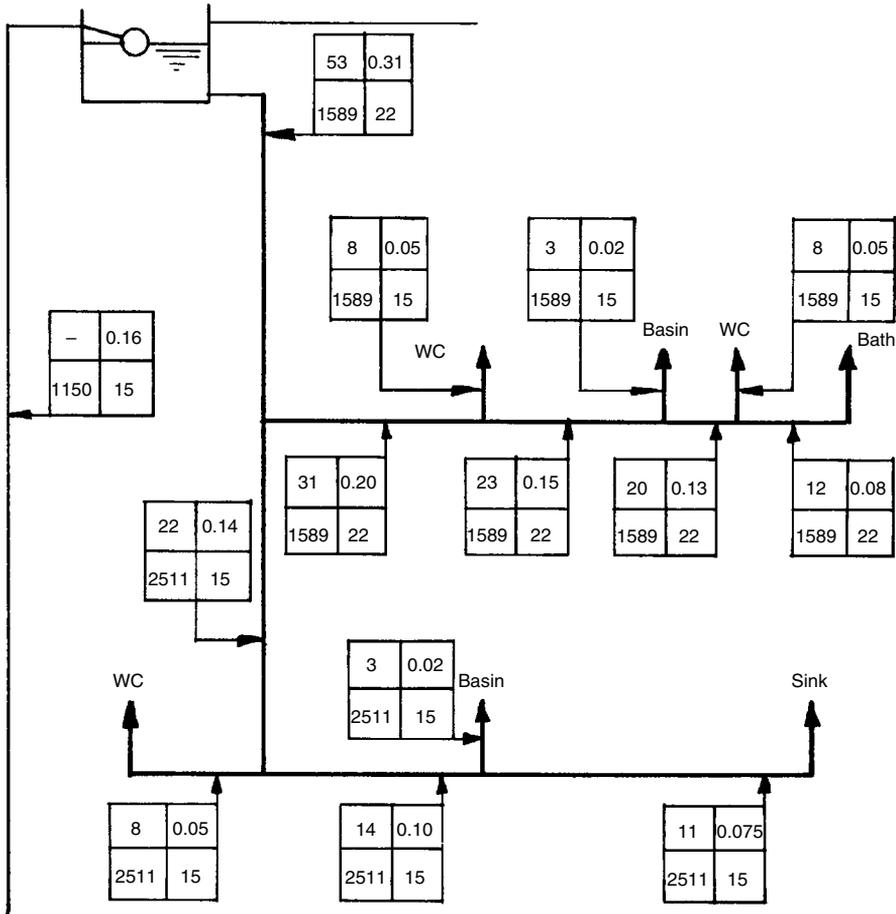
6.9 Pipe-sizing working drawing for Example 6.2.

The pipe-sizing data are shown in Fig. 6.9. Taps and ball valves will be 15 mm on domestic sanitary appliances and 22 mm on baths. *DU* values are taken from Table 6.2: WC, 8; basin, 3; sink, 11; bath, 12. These are entered into the appropriate boxes on the working drawing and then totalled back to the water main. Great accuracy is not needed in reading the water flow rates appropriate to each *DU*.

The heads of water causing flow are 4 m for the upper floor and 8 m for the lower floor. The measured length of pipe from the storage tank to the furthest fitting on the upper floor, the bath, is:

$$L_1 = (4 + 1 + 4 + 4 + 2 + 3 + 1) \text{ m} = 19 \text{ m}$$

and the equivalent length of the circuit to the bath is,

$$EL_1 = 1.3 \times 19 \text{ m}$$
$$= 24.7 \text{ m}$$

Similarly, the equivalent length for the lower floor circuit to the sink is:

$$EL_2 = 1.3 \times (4 + 1 + 3 + 1 + 4 + 10 + 1) \text{ m} = 31.2 \text{ m}$$

The head loss rate to the bath is:

$$\frac{H_1}{EL_1} = \frac{4\ m}{24.7\ m}$$
$$= 0.162\ \text{m head/m run}$$

The head loss rate to the sink is:

$$\frac{H_2}{EL_2} = \frac{8\ m}{31.2\ m}$$
$$= 0.2564\ \text{m head/m run}$$

The pipe circuit to the bath has the lowest $H/EL$ figure; this is the index circuit. $H_1/EL_1$ is the available pressure loss rate, which drives water through the upper part of the system. Branches to other fittings on the same floor level can be sized from the same figure. All pipes below the upper floor are sized using the value of $H_2/EL_2$ that is appropriate to that circuit. Now,

$$H = \frac{\Delta p}{9807}\ m\ H_2O$$

where $\Delta p$ is the pressure exerted by a water column of height $H$ m. Therefore

$$\frac{\Delta p_1}{EL_1} = \frac{H_1}{EL_1} \times 9807\ \text{N/m}^3$$
$$= 0.162 \times 9807\ \text{N/m}^3$$
$$= 1589\ \text{N/m}^3$$

and

$$\frac{\Delta p_2}{EL_2} = 0.2564 \times 9807\ \text{N/m}^3$$
$$= 2514.5\ \text{N/m}^3$$

These pressure loss rates are rounded and entered on Fig. 6.8. A different pressure loss rate could be calculated for each pipe but sizing them all on the index values is sufficiently accurate at this stage. Suitable pipe diameters are chosen from either Table 4.3 or Table 6.3, or the full data tables in CIBSE (1986). Notice that the bath connection size has been used rather than the 15 mm pipe, which would satisfy the design data for much of the upper floor branch. The lower water velocities produced will minimize noise generation in the pipework. The pressure loss rate causing flow in the water main is:

$$\frac{H_3}{EL_3} = \frac{\text{head available for overcoming pipeline friction}}{\text{equivalent pipe length}}$$

Now,

$$H_3 = \text{water main pressure} - \text{vertical lift} - \text{ball valve resistance}$$
$$- \text{water velocity pressure head at ball valve}$$
$$= 20 - (4 + 1 + 3 + 1) - 2\ m$$
$$= 9\ \text{m water guage}$$

and,

$$EL_3 = 1.3 \times (50 + 4 + 1 + 3 + 1) \, m = 76.7 \, m$$

Therefore,

$$\frac{H_3}{EL_3} = \frac{9 \, m \, water}{76.7 \, m \, run} = 0.1173 \, m \, water/m \, run$$

and,

$$\frac{\Delta p}{EL_3} = 0.1173 \times 9807 \, N/m^3 = 1150.4 \, N/m^3$$

While this pressure loss rate is available, a water main 15 mm in diameter would provide a flow of a little over 0.16 kg/s. Then, while the taps are shut, the storage tank would refill in:

$$230 \, kg \times \frac{s}{0.16 \, kg} \times \frac{1 \, h}{3600 \, s} = 0.4 \, h$$

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**EXAMPLE 6.3**

A hot-water service secondary system is shown in Fig. 6.10. Estimate the sizes of the pipes and specify the pump size.
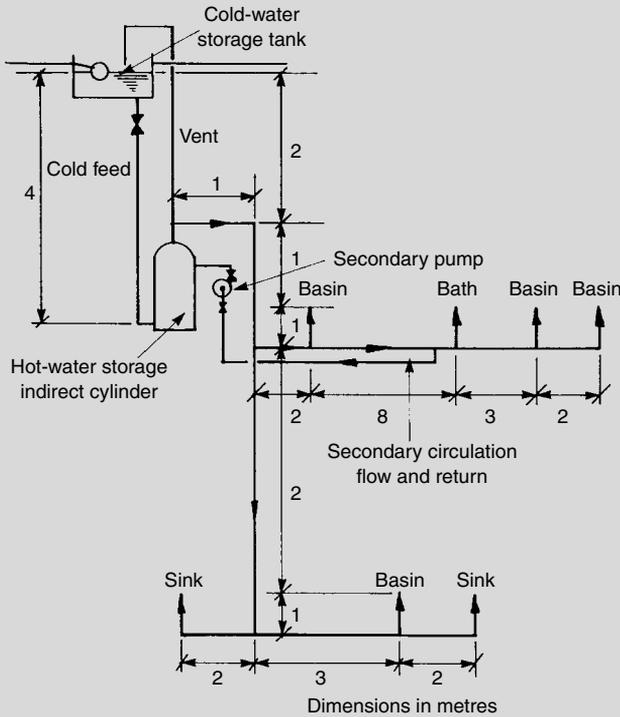


6.10  Secondary hot-water service system for Example 6.3.

Taps on the lower floor are within the limit for dead-leg non-circulating pipes and a secondary return is shown for the group of appliances on the upper floor. Figure 6.11 is the working drawing. Water flow through the cold-feed pipe into the indirect cylinder is at the same rate as the expected outflow. The pressure loss rate to X from the cold-water storage tank is:

$$\frac{H_1}{EL_1} = \frac{3 \text{ m head}}{1.3 \times 24 \text{ m run}}$$

$$= 0.0962 \text{ m head/m run}$$

Then,

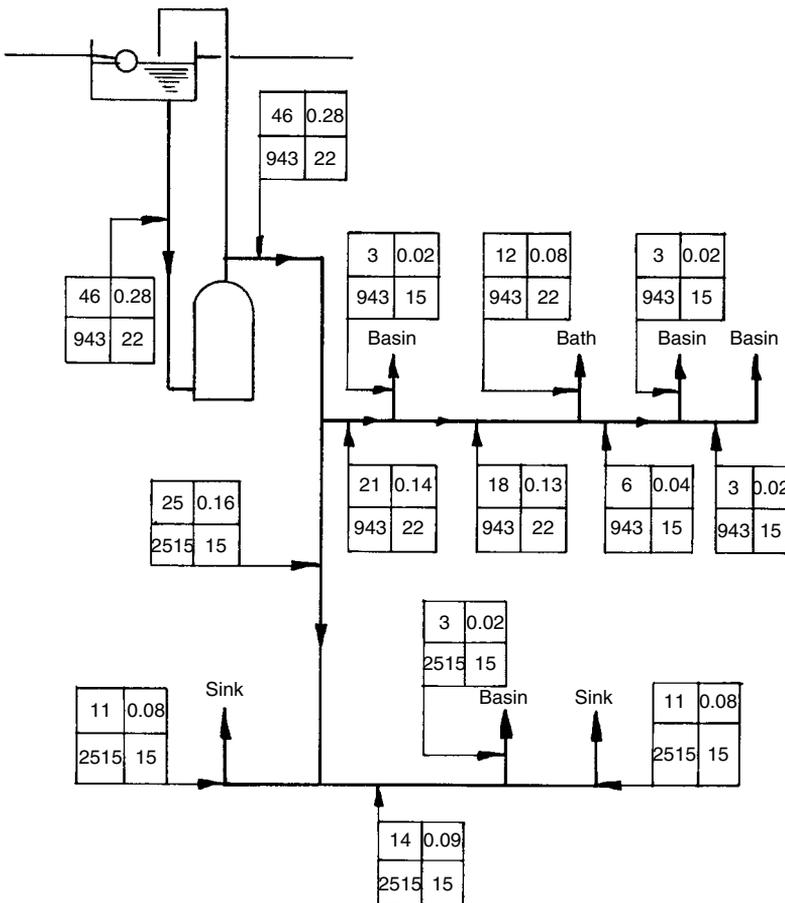$$\frac{\Delta p_1}{EL_1} = 0.0962 \times 9807 \text{ N/m}^3$$

$$= 943.4 \text{ N/m}^3$$



6.11 Hot-water service pipe-sizing working drawing for Example 6.3.

Table 6.4  Insulated pipe heat emission.

| Pipe diameter (mm) | 15 | 22 | 28 | 35 | 42 |
|---|---|---|---|---|---|
| Heat emission (W/mK) | 0.19 | 0.23 | 0.25 | 0.29 | 0.32 |

Source:  Reproduced from *CIBSE Guide* (CIBSE, 1986) by permission of the Chartered Institution of Building Services Engineers.

The pressure loss rate to Y is:

$$\frac{\Delta p_2}{EL_2} = \frac{6}{1.3 \times 18} \times 9807 \text{ N/m}^3$$

$$= 2514.6 \text{ N/m}^3$$

The secondary return pipe is not intended to play an active part in water discharge from the taps but only to pass an amount of water relating to circulation pipe heat losses. Pipes insulated with 25 mm glass fibre have heat emissions as shown in Table 6.4.
The heat loss from the secondary circulation is,

$$\text{heat loss} = 13 \text{ m} \times 0.23 \ \frac{W}{mK} \times (65 - 20) \text{ K}$$

$$+ 13 \text{ m} \times 0.19 \ \frac{W}{mK} \times (65 - 20) \text{ K}$$

$$= 245.7 \text{ W} = 0.2457 \text{ kW}$$

The water flow rate necessary to offset this pipe heat loss while losing say 5°C between the outlet and inlet connections at the cylinder is:

$$q = \frac{0.2457}{4.19 \times 5} \text{ kg/s}$$

$$= 0.0117 \text{ kg/s}$$

By reference to Table 4.3, a pipe 15 mm or 22 mm in diameter carrying 0.0117 kg/s has a pressure loss rate of much less than 200 N/m$^3$. A gross overestimate of the pump head for this circuit is:

$$H = 26 \text{ m} \times 1.3 \times 200 \times \frac{1}{9807}$$

$$= 0.69 \text{ m water}$$

A pump that delivers 0.0117 kg/s at a head of 0.69 m would meet the requirement. Pump C in Fig. 4.16 would provide a far higher flow rate than this, and either a smaller pump would be used or the control valves would be partially closed to avoid the production of noise due to high water velocities.

**Allocation of sanitary appliances**

The recommended numbers of sanitary fittings are given in Table 6.5.

Table 6.5  Recommended allocation of sanitary fittings.

| Building accommodation | No. of occupants | Male | Female | Urinals | Male | Female |
|---|---|---|---|---|---|---|
| Staff | 1–100 | 1 + 1 per 25 | 1 + 1 per 14 | 1 + 1 per 25 | 1 + 1 per 25 | 1 + 1 per 14 |
| | Over 100 | + 1 per 30 | + 1 per 20 | + 1 per 30 | + 1 per 30 | + 1 per 20 |
| Transient public | 1–200 | 1 per 100 | 2 per 100 | 1 per 50 | 1 per WC | 1 per WC |
| | 200–400 | 1 per 100 | + 1 per 100 | 1 per 50 | 1 per WC | 1 per WC |
| | Over 400 | + 1 per 250 | + 1 per 100 | 1 per 50 | 1 per WC | 1 per WC |

Source: Reproduced from *IHVE Guide* (CIBSE, 1986 [IHVE, 1970]) by permission of the Chartered Institution of Building Services Engineers.

Table 6.6  Allocation of sanitary accommodation for Example 6.4.

| Staff | Students |
|---|---|
| 2 male WCs | 4 male WCs |
| 2 female WCs | 4 female WCs |
| 2 urinals | 8 urinals |
| 2 male basins | 4 male basins |
| 2 female basins | 4 female basins |

**EXAMPLE 6.4**

A new university building is to have 70 male and 20 female staff. The student population is considered to be 400 males and 300 females. Students are considered to be transient public. Recommend a suitable allocation of sanitary accommodation.

Using Table 6.5, we obtain the results given in Table 6.6. The accommodation is to be distributed around the site to ensure uncongested access and reasonable walking distances. A tall building would ideally have toilets on each floor, close to the stairways and lifts, so that all the pipework can run vertically in a service duct. At least one toilet for disabled people is to be included at suitable location, with appropriate access, in the above schedule.

**Materials for water services**

The materials used in hot- and cold-water systems are listed in Table 6.7. Corrosion protection is provided by ensuring that incompatible materials are not mixed in the same pipework system, by recirculating the water in central heating systems to reduce fresh oxygen intake, and by adding inhibiting chemicals to the water. Hot- and cold-water service systems are continually flushed with fresh water, making it necessary to use galvanized metal, copper or stainless steel.

Copper and galvanized steel should not be used in the same system because electrolytic action will remove the internal zinc coating and lead to failure. A galvanized metal cold-water storage tank can be successfully used with copper pipework as the low temperature in this region limits electrolytic action. Heat accelerates all corrosion activity.

Black mild steel is used in recirculatory heating systems, and an initial layer of mill scale, which is metal oxide scale formed during the high-temperature working of the steel during its

Table 6.7  Materials for hot- and cold-water systems.

| Material | Application | Jointing |
| --- | --- | --- |
| Lead | Elderly hot- and cold-water pipes up to 22 mm; water becomes contaminated during storage in the pipework and must not be consumed | Hot molten lead-wiped joints and swaged (flared) connections to copper pipe |
| Copper | All water services, gas and oil pipelines; 6–10 mm soft copper tube supplied in rolls for oil lines and microbore heating; semi-hard tube in various thicknesses in diameters of 15 mm upwards; hand- or machine-formed large radius bends are popular; aluminium finned pipe is used in convector heaters | Compression, manipulative, silver solder, bronze weld, flanged or push-fit ring seal using polybutylene fittings |
| Black mild steel | Indirect hot-water heating systems, pipework and radiators | British Standard pipe thread (BSPT), screwed and socketed, flanged or welded |
| Galvanized mild steel | Hot- and cold-water pipework on open systems and water mains; cold-water storage tanks and indirect cylinders | BSPT screwed, socketed, flanged or welded |
| Stainless steel | Hot- and cold-water pipework 15–28 mm; thickness and diameter correspond to those of semi-hard copper and can be bent in the same way; larger diameters are used for chemicals or for sterile fluids in hospital services | Compression, silver solder, flanged or push-fit ring seal using polybutylene fittings |
| Cast iron | Central heating radiators, boilers and centrifugal pump bodies | BSPT-screwed fittings and gasket joints |
| Brass | Pipe fittings and valves | BSPT screwed |
| Gunmetal | Pipe fittings and valves; pump impeller; also body of a secondary hot-water service centrifugal pump | BSPT screwed |
| Polybutylene | Cold- and hot-water pipes and fittings in 15 m and 22 mm diameters, withstanding 90°C at 3 bar (atm) pressure | Push-fit ring seal, compression fusion weld |
| Polyethylene | Underground mains cold water | Compression |
| Unplasticized poly vinyl chloride (UPVC) | Mainly cold-water services | Compression, solvent weld |
| Cast aluminium | Boiler body, central heating radiators with convection fins | BSPT screwed |

manufacture, helps to slow further corrosion. Discoloration of the central heating water from rust to black during use shows steady corrosion. A black metallic sludge forms at low points after some years. Large hot-water and steam systems have the mill scale chemically removed during commissioning and corrosion-inhibiting chemicals are mixed with the water to maintain cleanliness and avoid further deterioration.

The formation of methane gas in heating systems during the first year of use is due to early rapid corrosion, and radiators need frequent venting to maintain water levels. Proprietary inhibitors should be added to all central heating systems. These control methods of corrosion are anti-bacterial. Without them, steel boilers and radiators can rust through in 10 years.

**Solar heating**

Solar heating can be employed to assist the generation of hot water in secondary storage systems with a consequent reduction in energy costs. The highly variable nature of solar radiation in the
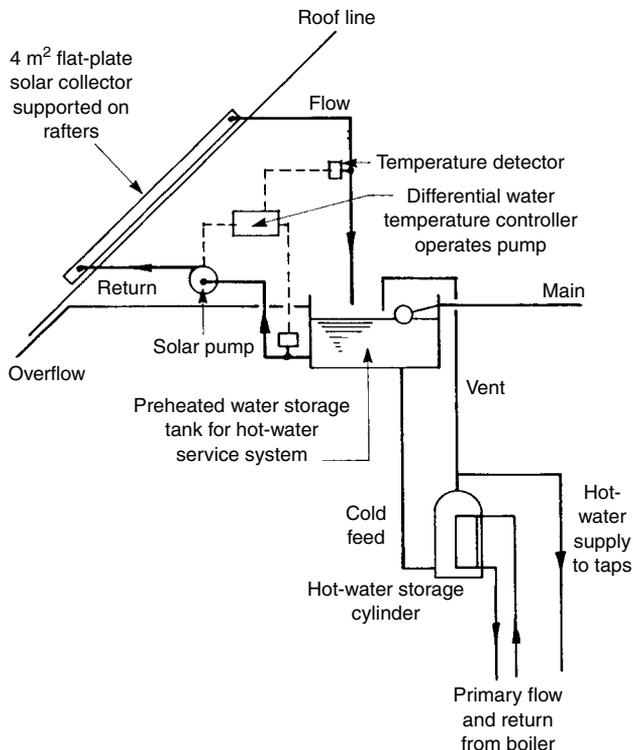
UK produces a financial return on the capital invested in equipment of around 10% per annum when electrical water heating is used. Solar energy is used to provide:

1.  comfort heating through architectural design in a 'passive' system;
2.  comfort heating using collectors, with air as the heat transfer fluid, in an 'active' system;
3.  comfort heating and hot-water using collectors, with water as the heat transfer fluid, in an active system.

Thermal storage of the collected energy is needed to balance the supply of solar heat with its times of use, usually when the supply has greatly diminished. The following methods of thermal storage are used:

1.  thick concrete or brick construction for passive systems, combined with large areas of south-oriented glazing;
2.  rock heat storage, heated by air recirculation;
3.  water tanks;
4.  phase change salts.

Flat-plate solar collectors are the most popular as they can heat water to 30–40°C without the danger of boiling. They can be incorporated into the architectural design of a sloping roof and are reasonably cheap. They are used to preheat the water supplied to the hot-water service storage cylinder, as shown in Fig. 6.12. Only the simplest arrangement is indicated, where the cold-water



6.12  Solar collector to preheat a hot-water service system.

(a)



Copper pipes brazed to
a copper sheet

Glass

Outer casing

Thermal insulation

(b)



Black-painted water
pipe along focal plane

Solar radiation

Polished aluminium
reflector

Tracked to follow the sun
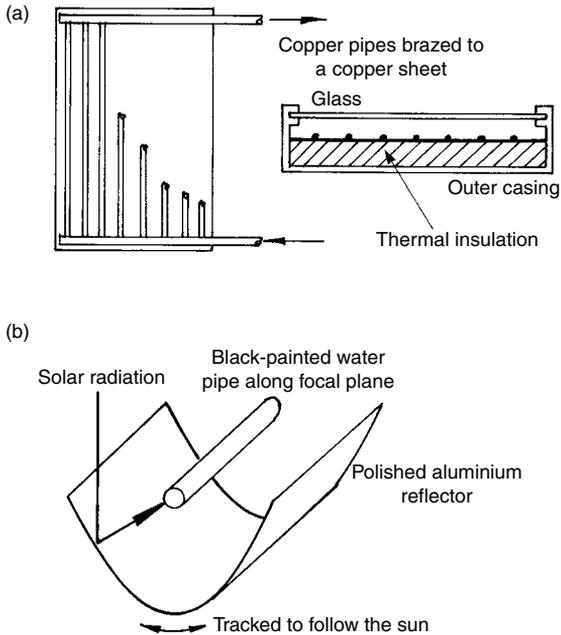
6.13 (a) Flat-plate solar collector; (b) parabolic trough concentrating solar collector.

storage tank supplies only the hot-water cylinder. A wide variety of system designs are in use, depending upon requirements. The solar pump switches off when the temperature sensors find no measurable water temperature rise. All the water then drains back into the storage tank to avoid frost damage. The system will be shut down during the coldest weather.

Concentrating solar collectors are used to generate water temperatures of 80°C and over for hot-water service heating or air-conditioning systems. They are usually driven by electric motors, through reduction gears, to track the sun's movement during each day so that the collecting pipe is kept in the focal plane of the parabolic mirror or polished aluminium reflector. Typical flat-plate and concentrating solar collectors are shown in Fig. 6.13.

**Questions**

1. Sketch and describe the earth's natural water cycle.
2. List and describe the sources of water and the methods used for its storage and treatment.
3. What pollutants are present in naturally occurring water and where do they come from?
4. Explain the terms 'temporary' and 'permanent' hardness, and list their characteristics.
5. State the use of service reservoirs and describe mains water distribution methods.
6. State the design parameters for cold-water mains and storage systems within buildings, giving particular information on protection from frost damage, suitability for drinking and protection of the mains against contamination from the building.
7. List the design parameters for hot-water service systems, giving typical data.
8. Sketch the layout of a water services system in a house, showing typical sizes of equipment and methods of control. Show how wastage of water is minimized.
9. Sketch and describe the methods used to generate hot water, noting their applications, economy and thermal performance.

10. Sketch and describe a suitable cold-water services installation for a 20-storey hotel where the mains water pressure is only sufficient to reach the fifth floor.

11. Draw the layout of an indirect hot-water system employing a central heating boiler and secondary circulation. Show all the pipework and control arrangements.

12. A small hotel is designed for 20 residents and 4 staff. Hot water to be stored at 65°C is taken from a cold-water supply at 10°C and heated during a 4-h period. Calculate the heat input rate required.

13. Explain the meaning and use of 'demand units'.

14. The cold-water service system in Fig. 6.9 has three identical sanitary fittings in the locations shown for each type. The pipe lengths shown are to be multiplied by 1.5 but vertical dimensions remain the same. Calculate the pipe sizes.

15. A cold-water storage tank in a house with five occupants is to have a capacity of 100 l per person and be fed from a water main able to pass 0.25 l/s. How long will it take to fill the tank?

16. A secondary hot-water service system has 55 m of 28 mm circulation pipework and 40 m of 15 mm circulation pipework. Water leaves the cylinder at 65°C and returns at 60°C. Air temperature around the pipes is 15°C. Pressure loss rate in the pipework is 260 $N/m^3$. The frictional resistance of the pipe fittings is equivalent to 25% of measured pipe length. Specify the head and flow rate required for the secondary circulation pump and choose a suitable pump. Use Table 4.3 and Fig. 4.9.

17. A bank building is to house 115 male and 190 female staff. Recommend a suitable allocation of sanitary accommodation.

18. Draw cross-sections through four different types of pipe joint used for water services, showing the method of producing a water seal in each case.

19. List the factors involved in the provision of a pipework system for the conveyance of drinking water within a curtilage. Comment on the suitability, or otherwise, of jointing materials, lead pipes and storage tanks in this context.

20. Describe the corrosion processes that take place within water systems and the measures taken to protect equipment.

21. Sketch and describe the ways in which solar energy can be used within buildings for the benefit of the thermal environment and to reduce primary energy use for hot-water production. Comment on the economic balance between capital cost and expected benefits in assessing the viability of such equipment.

22. List the types of sanitary appliance available and describe their operating principles, using appropriate illustrations. Comment on their maintenance requirements, water consumption, long-term reliability and materials used for manufacture.

23. How can water usage be minimized in domestic hot- and cold-water systems?

    1. Throttle pipe circuit balancing valves to minimize maximum water flow rates.
    2. Provide all water outlets from high-level storage tanks.
    3. Use spray taps on washbasins, low-flow shower heads, dual flush toilets and urinal occupancy sensors.
    4. Reduce washing and toilet facilities to below recommended numbers.
    5. Cannot be reduced as people have to use a certain amount for each facility.

24. The Demand Unit for domestic hot- and cold-water service outlets is based upon:

    1. Maximum sink water flow of 2.5 l/s at 1-h intervals.
    2. Total water flow required by a group of basin, sink, shower, bath and WC during average usage pattern.

3.  Demand Unit is just a fictitious number.
4.  Demand Unit is 1.0 for a domestic basin cold-water tap water flow rate of 0.15 l/s for a duration of 30 s and an interval between use of 5 min.
5.  100% usage in a typical house group of appliances.

25. What is reverse osmosis?

1.  Osmotic pressure difference cannot be reversed.
2.  A natural phenomenon.
3.  The opposite of water diffusion through a semi-permeable membrane to equalize the concentration of salt in solution.
4.  Dissolved salts migrating through a membrane, leaving desalinated water behind.
5.  Heat and pressure applied to salty water causes water molecules to pass through a fine membrane into a desalinated water stream on the other side.

26. Which of these is the correct basic safety provision for the public mains water supply system?

1.  Stop valve as mains water enters each building.
2.  Backflow preventer valve on each mains water pipe entering a building.
3.  Ball valve on a cold-water storage tank.
4.  Toilet flushing cistern.
5.  Air gap beneath every ball valve and tap outlet.

27. Should domestic potable cold water rise above the safe distribution temperature, what must be done?

1.  Redesign the distribution system and reinstall new pipes.
2.  Test water temperature, insulate pipes, drain and flush system, cool the mains water with a refrigeration system.
3.  Evacuate the building, drain and flush system.
4.  Nothing, it will soon cool down again.
5.  Test water temperature, find cause of heating, insulate or reroute pipes, drain and flush system and if necessary disinfect the system pipes and tanks.

28. Why is domestic hot water stored at high temperature?

1.  Maximizes the thermal efficiency of the water heater.
2.  Minimizes pipe sizes for flow rates.
3.  Minimizes storage quantity.
4.  It should not be as it can scald users.
5.  Kill Legionella bacteria in water.

29. What is part of the primary water treatment of public water supply systems in the UK?

1.  Aeration in outdoor reservoirs.
2.  Filtration by water percolating through the ground.
3.  Pumped filtration through granite chippings.
4.  Flocculation in gravel beds.
5.  Slow filtration by gravity flow through sand and activated carbon beds.

30. Which water description is correct about soft water?

1.  Occurs in granite rocky soil parts of the country.
2.  High pH value.

3.   Low suspended salt concentration.
4.   Total dissolved salt concentration of over 200 ppm.
5.   High soap-destroying capability.

31.  Which water description is correct about hard water?

1.   Occurs in chalk soil parts of the country.
2.   Very low pH value.
3.   High suspended salt concentration and suspended vegetable matter.
4.   Total dissolved salt concentration below 50 ppm.
5.   Laundries consume minimal soap.

32.  Which causes temporary hardness in water?

1.   Suspended solids.
2.   Acidic ground water sources.
3.   Precipitation of salts during storage in the building.
4.   Sulphates and chloride salts in the water.
5.   Dissolved carbonate salts.

33.  Which is correct about permanent water hardness salts?

1.   Cannot be removed from water.
2.   Only removed by steam generation and condensation.
3.   Salts deposited on heat transfer surfaces during water boiling.
4.   Only removable by dosing ground water with acid.
5.   Due to presence of non-carbonate dissolved salts.

34.  Which is not correct about water pH value?

1.   A measure of free hydrogen ions in water.
2.   pH of 7 means water is neither acidic nor alkaline.
3.   pH below 7 is always found in hard water.
4.   Steam boiler water is treated to a pH of 11.
5.   Acidic water from granite ground has a low pH.

35.  Which is correct about water treatment for closed-circulation water systems?

1.   Not needed.
2.   Water purifies itself due to release of dissolved oxygen and salts during commissioning.
3.   Absence of fresh oxygen in closed system avoids need for corrosion treatment.
4.   There is no difference between the affects of pH value, acidity, alkalinity and corrosiveness of water.
5.   Treatment provided to combat electrolytic corrosion.

36.  Which applies to the base exchange water treatment system?

1.   Calcium carbonate in public mains water chemically reacts with sodium zeolite in treatment tank.
2.   Calcium carbonate in public mains water is absorbed by zeolite salt in the treatment tank and remains there.
3.   Zeolite salts are consumed by incoming hardness salts and residue has to be removed for disposal.
4.   Zeolite salts filter out calcium carbonate and other hardness salts and must be disposed to waste water when fully clogged.

     5.    Zeolite salts destroy hardness salts in the public mains water supplied to steam boilers.

37.  What is the meaning of low-pressure water supply main?

     1.    Building has a pressure reduction valve on the incoming public water main.
     2.    Street water main is at very low pressure.
     3.    There is no such thing as all public water supply systems function at well above atmospheric pressure.
     4.    All water services in buildings below four-storey height.
     5.    Mains water pressure supplies storage tanks that service the building's systems.

38.  Which is the minimum allowable pressure of a water main in the street?

     1.    100 bar.
     2.    10 atmospheres.
     3.    30 m water gauge.
     4.    100 kPa.
     5.    10 000 kPa.

39.  When mains water pressure in the street is 250 000 $N/m^2$ and pipe friction and discharge losses are negligible, what building height can water lift to?

     1.    250 m.
     2.    9.807 m.
     3.    26 m.
     4.    12 storeys.
     5.    25.49 m.

40.  The measured pressure in the water main in the street is 3.5 b. To what height could the pressure of the water accommodate?

     1.    35.6 m.
     2.    0.35 m.
     3.    3.5 m.
     4.    356.8 m.
     5.    35.0 m.

41.  Which technical feature ensures a consumer building does not contaminate the public water supply pipework system?

     1.    Non-return valve on the supply pipe to each building.
     2.    Manual isolating valve at each building entry pipe.
     3.    Maintaining the building's piped water systems at a lower pressure with a pressure-reducing valve at entry from the public main.
     4.    Dosing all pipe systems in a building with biocide.
     5.    An air gap.

42.  What is a water-pressure-boosting system?

     1.    Public mains water pumping station.
     2.    Gas-fired storage water heater to raise water pressure.
     3.    Sump pump to remove flood water.
     4.    Circulating pump for heating, chilled water or domestic hot water.
     5.    Pump to raise water to floors above where the public mains pressure can reach.

43. What does central domestic hot-water storage system mean?

    1. Hot-water storage tank in the middle of a building.
    2. Centrally heated storage calorifier.
    3. Domestic hot-water storage cylinder with pipework distribution to all hot-water taps.
    4. Gas-fired storage water heaters.
    5. Electrically heated domestic hot-water unit near each tap where the power is generated from the public system.

44. What is an instantaneous domestic hot-water unit?

    1. One where opening a hot-water outlet causes immediate flow.
    2. Gas-fired non-storage water heat exchanger.
    3. Something like a kettle.
    4. Electrically heated insulated storage water heater located beneath, alongside or above a hot tap outlet.
    5. Large domestic hot-water storage calorifier that cannot run out of hot water.

45. What is the health risk, if any, from stored domestic hot water?

    1. No health risk when public mains water is heated and stored as it always remains dosed with drinkable chemicals.
    2. Heating water does not raise its health risk.
    3. Only mains water that has come into contact with the atmosphere could become contaminated.
    4. Mains water bacteria always remain dormant.
    5. Legionella bacteria present in water grow rapidly between 20°C and 40°C.

46. How do we protect ourselves from domestic hot-water systems?

    1. Heat and store hot water at 42°C.
    2. Only use hot water at less than 45°C.
    3. Water stored at 65°C so all bacteria killed.
    4. Heat stored water to 65°C to kill bacteria, then wait for it to cool to 40°C prior to use.
    5. Heat stored water to 100°C to sterilize bacteria, then wait for it to cool to 40°C prior to use.

47. Which is the hotel domestic hot-water storage requirement in litres at 65°C, per person?

    1. 35
    2. 25
    3. 65
    4. 45
    5. 120

48. What is a domestic hot-water circulation system called?

    1. Personnel circulation.
    2. Hot-water pipe system.
    3. Tap circulation.
    4. Draw-off circulation system.
    5. Hot-water secondary flow and return.

49. A 1000 l domestic hot-water storage calorifier has a heating water rate of input of 50 kW. How long will it take to raise the water content from 10°C to 65°C if heat loss from the cylinder is negligible?

    1.  0.305 h.
    2.  3 days.
    3.  1.5 h.
    4.  1.28 h.
    5.  6.5 h.

50. Why are domestic hot- and cold-water distribution pipes not designed to always provide full flow when all taps are open?

    1.  But they are, have to be.
    2.  Users rarely open taps fully.
    3.  Pipe resistance always slows water flow, so full flow rate is never possible.
    4.  Demand for water at taps, showers and washing machines is randomly intermittent.
    5.  If too many taps open simultaneously, users simply have to wait a few seconds longer.

51. What does 'demand unit' stand for?

    1.  Amount of hot water needed to fill a standard basin in one minute.
    2.  Maximum demand for hot water from a group of taps.
    3.  Statistical assessment of the simultaneous flow in litre/s from a system of hot- or cold-water outlets.
    4.  Number relating to water flow rate, tap discharge time and interval between usage.
    5.  Total water flow rate demand in a system divided by the number of taps.

52. Which is the value of demand units?

    1.  Litre/s.
    2.  Total litres.
    3.  Time interval.
    4.  Number of water outlets.
    5.  Dimensionless.

53. Which is the appropriate temperature for shower, tap and bath water to avoid scalding?

    1.  36°C.
    2.  65°C.
    3.  50°C.
    4.  45°C.
    5.  41°C.