Part 2
Hot and Cold Water Supplies

Classification of Water

Water is a compound of hydrogen and oxygen. When we burn natural gas (a hydrocarbon, CH_4) dihydrogen monoxide (H_2O, i.e. water) and carbon dioxide (CO_2) are obtained as combustion products.

Pure water is a transparent, tasteless liquid which can be found in three physical states: solid (ice), liquid (water) or gas (steam or vapour). At atmospheric pressure, between 0 to 100°C, water is a liquid. At 0°C, water changes to ice with an immediate expansion in volume of 10%. At 100°C, it changes to steam, its volume expanding some 1600 times.

To convert water back to its constituent elements, an electric current needs to be passed through the liquid.

Rain water is usually contaminated with gases or chemicals which it absorbed as it fell. When rainwater reaches the ground it dissolves any soluble salts. Depending on which salts the water contains it may be classified as hard or soft.

Soft water

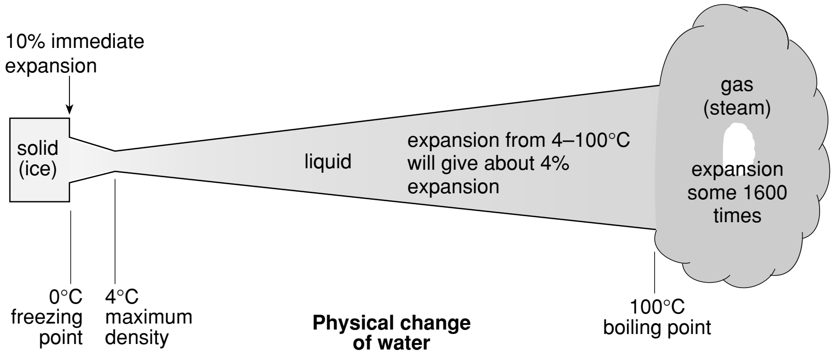
This is water which is free from dissolved calcium salts. Naturally occurring soft water is slightly acidic due to absorbed gases such as CO_2. Soft water tends to be more pleasant for washing in but has the major disadvantage of corroding pipework, lead pipes in particular.

Hard water

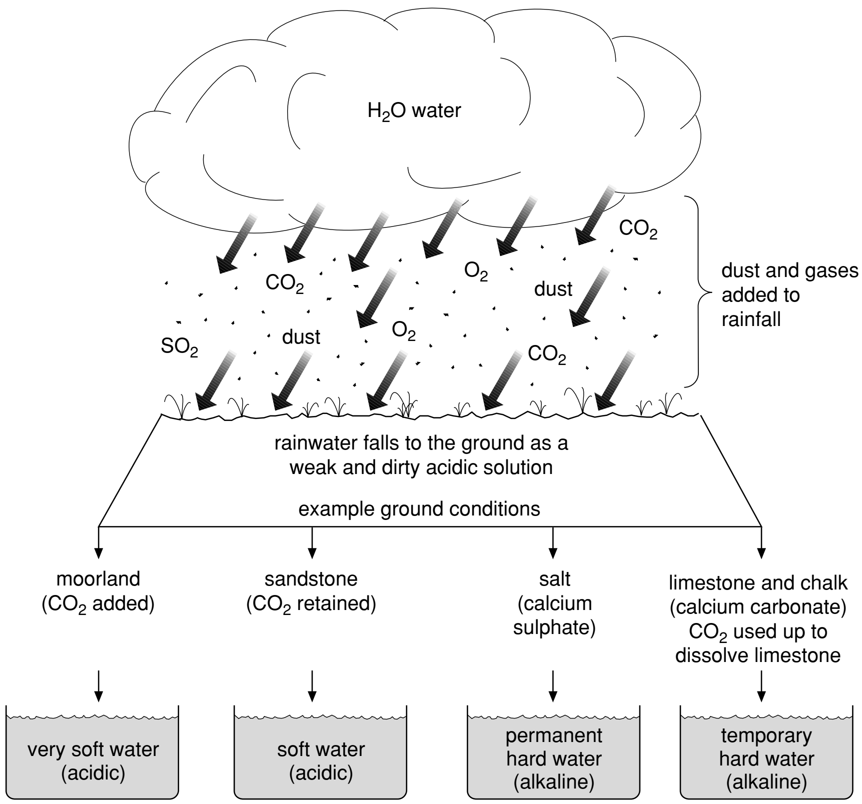
This is water which has fallen on, and filtered through chalk or limestone from which it dissolves small amounts of calcium and magnesium salts. The water may be either permanently or temporarily hard.

Permanent hardness This is the result of water containing calcium or magnesium sulphates. Boiling has no effect on permanent hardness.

Temporary hardness This is the result of the water containing calcium or magnesium hydrogen carbonates. The CO_2 dissolved in rainwater can attack limestone or chalk and convert the calcium carbonate and magnesium carbonate in the rock to soluble hydrogen carbonates. This temporary hardness can be removed by boiling the water; as a result CO_2 escapes into the air and calcium carbonate is precipitated as scale.



Physical change of water



Section of pipe with evidence of limescale

Classification of water

Cold Water to the Consumer

Relevant British Standards
BS EN 806-2 and BS 6700

Throughout the United Kingdom, wholesome water (i.e. water fit for human consumption) is provided by the local water authorities to individual premises and various industries. When a supply of water is required, the water authority will supply water to a point just outside the property boundary line where, nowadays, a meter is usually installed to calculate the amount of water consumed. From this point the supply pipe is run into the premises, with precautions being taken to protect the pipe from movement, frost damage and corrosive soil.

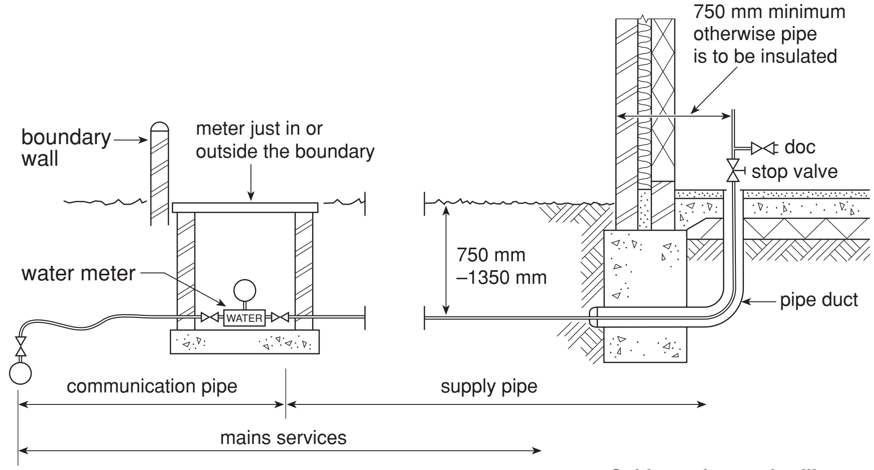
Any pipe passing through or under a building must be ducted. This allows for its removal should the need arise. A consumer's stop tap is fitted where the supply pipe enters the building and should be fixed as low as possible with a drain-off cock immediately above it. (Note that older properties do not have meters.) The pipe is run from this point to feed the various systems of cold water supply. It is the responsibility of the installer to comply with the Water Supply Regulations 1999 when connecting to the supply main. These regulations have been designed in order to prevent wastage, contamination and erroneous measurement of water.

Wastage of water This could be the result of undue consumption, misuse or simply a faulty component, such as a leaking valve. To prevent this, water meters are being installed to register the amount of water used in serving the premises, for which the owner/occupier will eventually be invoiced. As a means of combating the problem of wastage, the installer must provide the dwelling with suitable overflow/warning pipes from cisterns to let the user know of a fault, and a means of isolation must be provided to allow its speedy shutdown. Allowance for thermal movement, frost protection, etc., must be made in order to prevent damage.

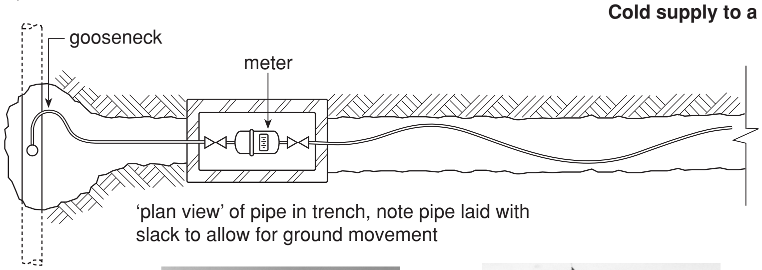
Water contamination The Water Supply Regulations include a list of five 'fluid categories' to identify the quality or condition of water, ranging from wholesome (fit for human consumption) to a level which presents a serious health risk. In very basic terms, the Regulations seek to ensure that once water has been drawn off for use, it should never be allowed to re-enter the water supply distribution network. There are several means by which water may be inadvertently contaminated. For example, it is possible that water may be sucked up from sanitary appliances (back-siphonage), such as baths and sinks, owing to peak flow demands creating a negative pressure on the supply pipe.

Contamination can also result from the use of unsuitable materials. Lead, for instance, is dissolved by water and as a result its use is prohibited nowadays. Even the solder used to join copper pipes, when used for hot or cold supplies, must be lead-free.

Erroneous measurement This refers to the discrepancy between the measurement or metering of water used and the quantity of water actually accounted and paid for.



Cold supply to a dwelling



Typical water meter

Frost damage to valve (causing wastage of water)

Hose connected to a tap without backflow protection (causing possible contamination)

Cold water to the consumer

Backflow Prevention

Backflow is a flow of water contrary to the intended direction of water flow. It can be caused due to **back pressure** or **back siphonage**.

- *Back pressure* is the result of water pressure in the system being greater than that in the supply. Higher system pressures can be caused by the expansion of water in unvented dhw supplies, or in systems where a pump is used.
- *Back siphonage* occurs as the result of negative pressures in the supply main, which may be caused by a major leak in the main or the fire services drawing off vast amounts of water.

Backflow prevention is achieved either by using a mechanical device or by a pipe arrangement which physically disconnects the supply from the system, maintaining an air gap. There are various backflow prevention devices, including single and double checkvalves and anti-vacuum valves. The Water Regulations list no less that 10 air gap configurations and 14 mechanical device combinations to combat the many scenarios where backflow could occur. The method selected would depend upon the severity of the risk; this is based upon the fluid risk category of the water that may be affected.

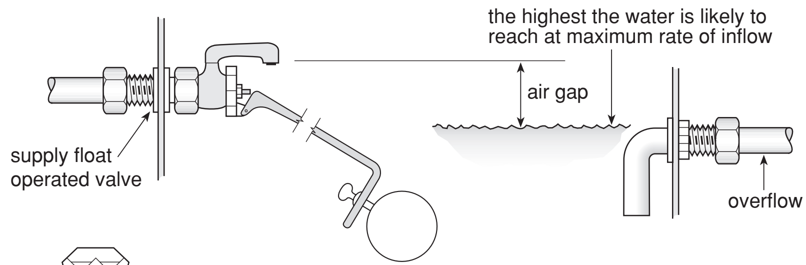
Fluid risk categories Schedule 1 of the Water Supply Regulations identifies five fluid categories:

Category 1: No health risk. Wholesome drinking water
Category 2: Aesthetic quality is impaired due to, for example, being heated
Category 3: Slight health hazard due to contamination with substances of low toxicity
Category 4: Significant health hazard due to toxic substances, e.g. pesticides
Category 5: Serious health risk. Contains pathogenic organisms, e.g. from human waste.

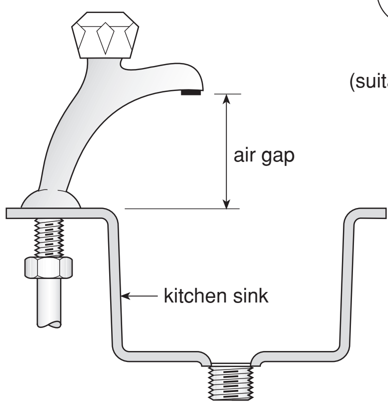
Verifiable and non-verifiable checkvalves Where a checkvalve incorporates a test point it is referred to as a verifiable check valve. A single check valve would be suitable where the fluid risk is only category 2. However for fluid risk 3, a double check valve would be required.

Reduced pressure zone valve (RPZ valve) This is a comparatively new valve to the UK and is used to protect against fluid risk 4 applications, such as a fire sprinkler system filled with antifreeze in a commercial premises. It can only be installed by an accredited installer, approved by the water supplier. It should be tested for correct operation every year, with a test certificate issued. It should be noted that no drinking water should be drawn off downstream of the RPZ valve. It sometimes creates a drop in pressure and therefore is not suited to low pressure supplies.

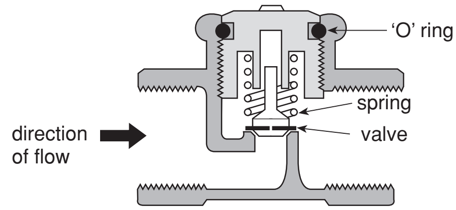
Shown opposite are a few examples of backflow prevention methods, including air gaps and mechanical devices identifying the fluid risk they are suited to.



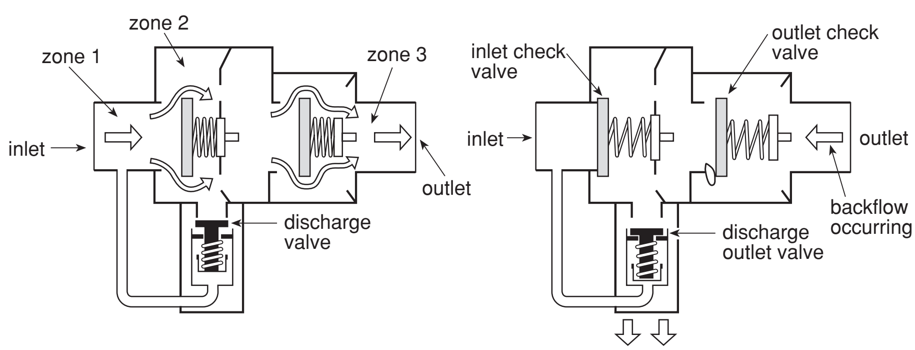
Type AG air gap
(suitable for fluid category 3)



Type AUK3 air gap
(suitable for fluid category 5)

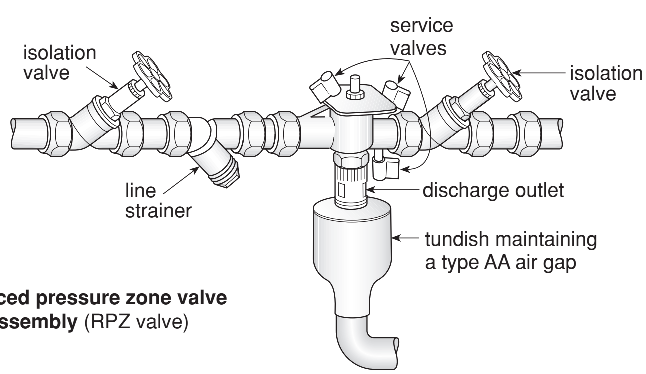


Non-verifiable single check valve
(suitable for fluid category 2)



'Flow position' 'Safety shut-off position'

Operation of an RPZ valve



Reduced pressure zone valve
Assembly (RPZ valve)

Cold Water Systems

Relevant British Standards
BS EN 806-2 and BS 6700

Two distinct systems of cold water supply are in use – the direct and indirect systems – although modified systems are to be found, in which several appliances are on the mains supply and several fed from a cistern. It is essential that the plumber obtains advice and gives written notice of the design of a new system to the local water authority before commencing work. Failure to do this may mean a contravention of the Water Supply Regulations 1999. Whatever system is chosen, it must be designed to deliver cold water at the point of use at a temperature not exceeding 25°C.

Direct system

In this system, all the cold water in the house is fed 'directly' from the supply main. The water pressure is usually high at all outlets, so this system can have the disadvantage of being more prone to water hammer. In some areas of the UK the supply pressure is reduced at peak times. This can cause a negative pressure in the pipeline and loss of supply. Also, precautions need to be taken to prevent back-siphonage of foul water from appliances into the supply pipe.

The direct system is cheaper to install than the indirect, and does not require a roof space to accommodate the cistern. However, peak flow times must be considered and, above all, adequately sized pipes used to prevent a lack of suitable flow, should several appliances be used at once.

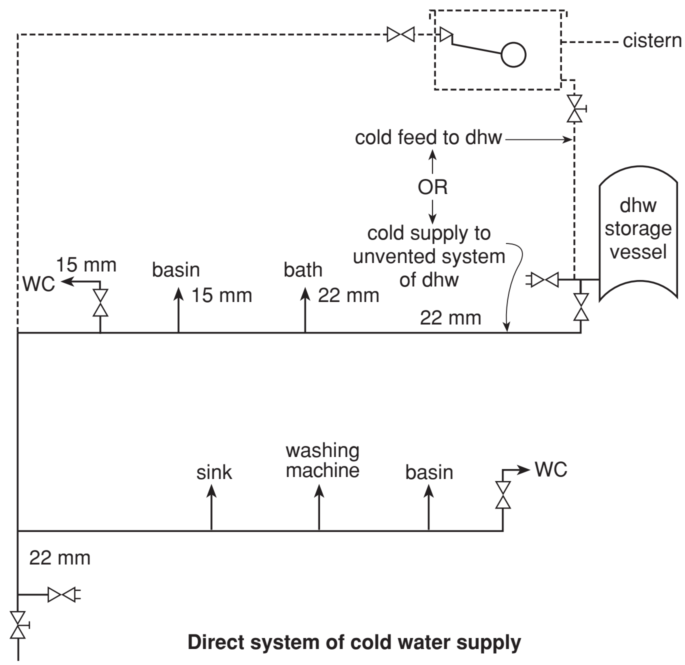
Indirect system

In this system, only one draw-off point (i.e. the kitchen sink) is fed from the mains supply pipe. All other outlets are supplied via a cold storage cistern, usually located in the roof space. Water pressure is usually much lower than with the direct system, but it will be maintained, even at peak times or during complete shutdown of the supply. Today in modern housing, with suitable precautions to storage cistern sizing and the prevention of water contamination, stored water is regarded as wholesome (fit for human consumption) so water from draw-off points other than the mains one is regarded as drinking water and, therefore, the same precautions must be maintained to prevent back-siphonage.

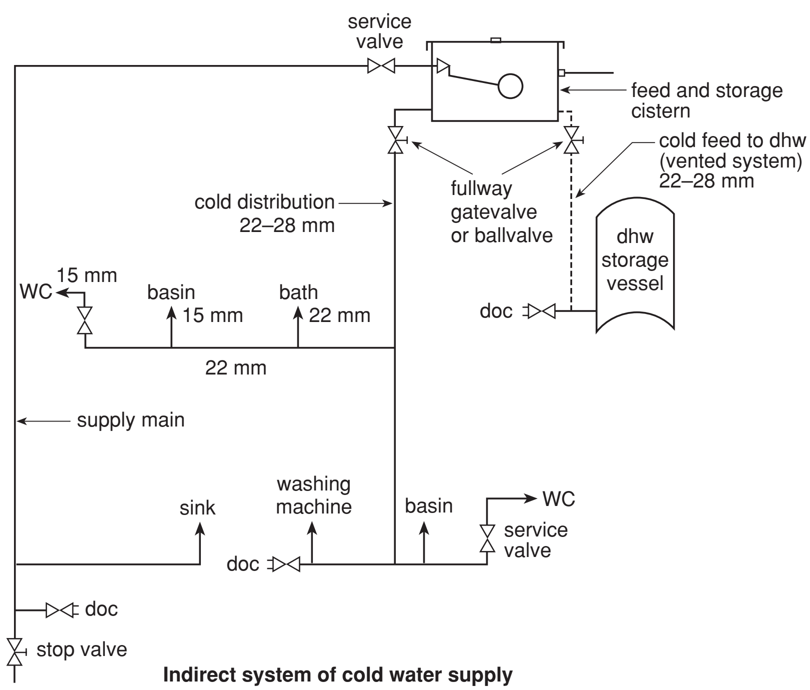
Cold supply to the domestic hot water (dhw) system

Unvented systems These systems are fed directly from the mains supply pipe. The biggest consideration is whether the supply main is large enough in diameter to provide a good flow rate should several appliances be operated at once. To prevent the hot water flowing back down the feed pipe, a check valve must be incorporated (see Unvented Domestic Hot Water Supply, page 106).

Vented systems These require a supply via a cold feed cistern. The cold feed pipe is run separately from any cold distribution pipework to prevent hot water being drawn off when the cold supply is opened.



Direct system of cold water supply



Indirect system of cold water supply

Cold water systems

Cold Water Storage

Relevant British Standards
BS EN 806-2 and BS 6700

When cold water needs to be stored to supply an indirect system of cold water, or to feed a system of dhw, it is held in a cistern which is usually located in the roof space.

The storage cistern should have a minimum capacity of 100 litres. If the cistern is also to act as a feed cistern for the hot water supply (being a combined storage and feed cistern), it should have a minimum capacity of 230 litres.

Cold distribution pipes from storage cisterns should be connected so that the lowest point of the water outlet is a minimum of 30 mm above the base of the cistern. This is to prevent sediment passing into the pipework. Connections of feed pipes to hot water apparatus from cisterns should be at least 25 mm above cold distribution pipes, if applicable. This should minimise the risk of scalding should the cistern run dry.

The float-operated valve (ballvalve) is fitted as high as possible and must comply with BS 1212, parts 2 or 3, thus maintaining an air gap and preventing back-siphonage. Overflow pipes should have a minimum internal diameter of 19 mm and in all cases be greater in size than the inlet pipe.

To prevent the ingress of insects, a tight-fitting lid must be provided, with a screened air inlet. Where a vent pipe passes through the lid, the pipe must be sleeved. Overflow warning pipes must also incorporate a filter or screen. Finally, the whole installation (cistern and pipes) must be insulated to prevent freezing.

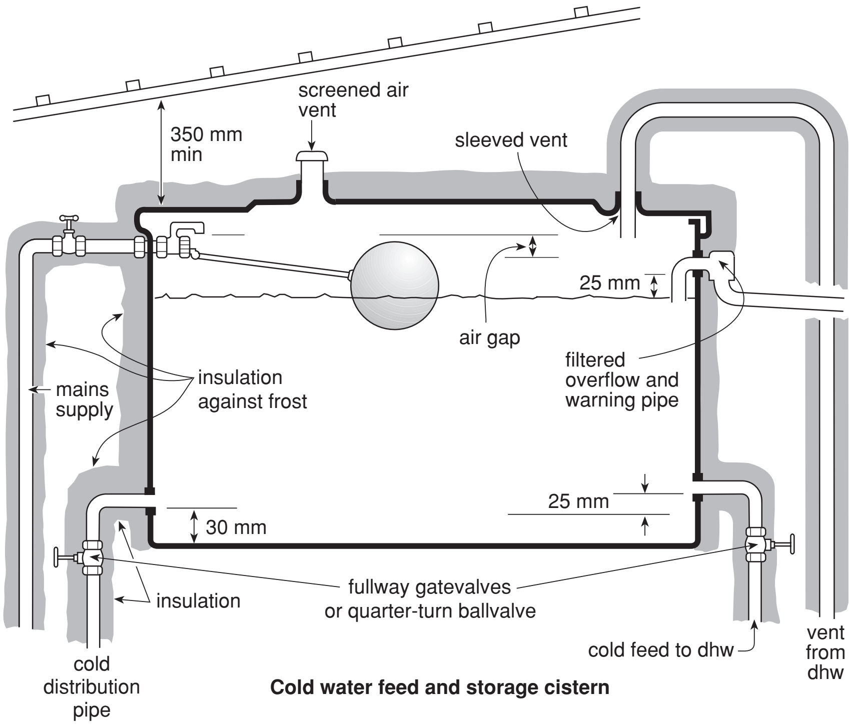
Coupling of storage cisterns

In larger commercial properties it is desirable to have two or more cisterns coupled together instead of one large cistern. This is beneficial because one of them can be isolated and drained down, if required. Equally, on a smaller scale, lack of space in a house sometimes limits the size of a storage cistern. In such a case, two smaller cisterns can be joined together to give the required capacity. Different methods are used for the above examples. If the need arises to isolate one cistern, an isolating valve is fitted at each point in or out of the cistern, which can be shut off. For the purposes of a domestic house, it would be uncommon for one cistern to be isolated, so the mains supply is usually taken into one cistern and the cold distribution or feed pipe is taken out of the other. By designing it in this way the water in the second cistern would not become stagnant.

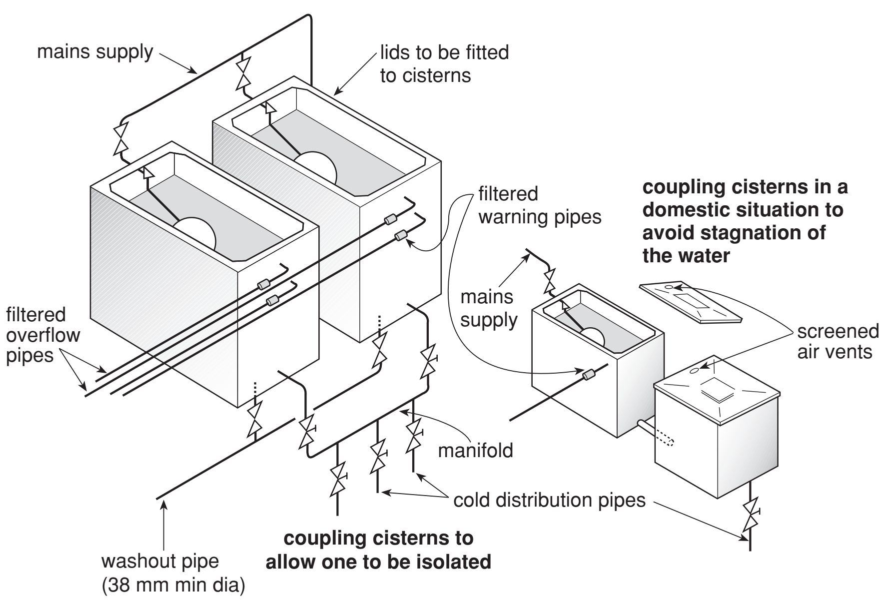
The washout pipe shown in the figure is only used on large cisterns (those holding over 2300 litres), for the purpose of draining down and cleaning out any sludge deposits, etc.

Cold supplies to be kept below 25°C

The Water Supply Regulations state that no cold water supplies should be warmed above 25°C. This requirement is to ensure water is not drawn off and wasted, but also reduces the growth of bacteria such as Legionella. Critical temperatures are between 25° and 50°C; therefore it may be necessary to insulate pipes to prevent them becoming too warm due to heat gain.



Cold water feed and storage cistern



Cold water storage

Water Treatment

Relevant British Standard
BS 7593

Before water is supplied to the consumer it is treated and purified by the water authority. When it arrives at the supply point, usually no more treatment is required. However, in hard water areas, where there are varying amounts of calcium salts in the water, it is sometimes desirable to treat the water to prevent excessive scale problems or provide a better liquid with which to wash (e.g. a laundry). The installation of a water softener or a water conditioner fulfils this purpose.

Water softeners

These soften hard water by passing it through a pressure vessel containing zeolites or a resin which absorbs the calcium in the water. After time, the zeolites become exhausted because they become saturated with calcium; they thus need to be regenerated with common salt. This is done automatically, by a system of backwashing which is timed to operate at around 3 AM via a timeclock or flow metering system, thus causing no inconvenience to the householder. Before installing the softener inlet connection, a branch pipe should be taken from the mains to provide a hard water drinking supply.

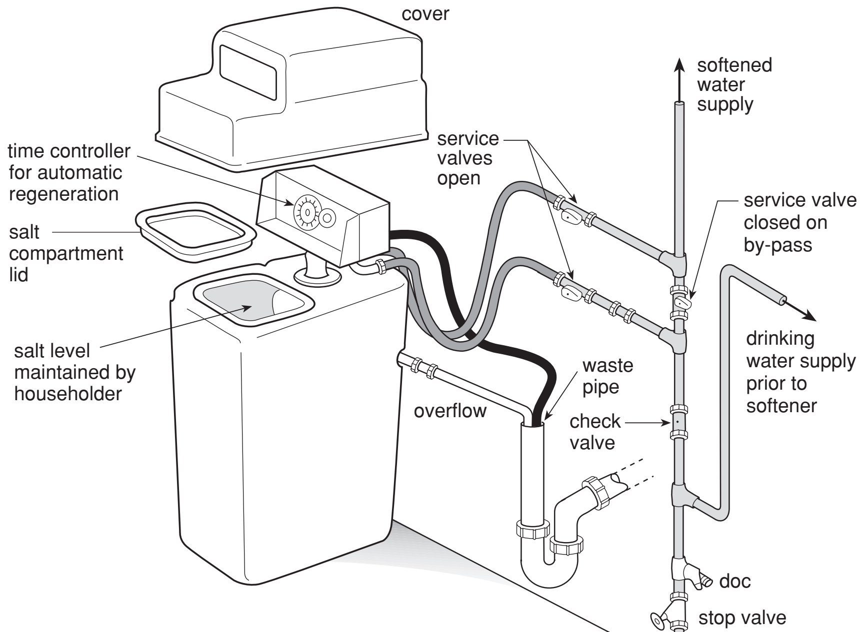
The installation of a water softener is quite straightforward, the connections being made in the way shown in the figure.

Water conditioners

Water conditioners do not soften water, they just stabilise the calcium salts which are held in suspension. There are two basic types of water conditioner: those that use chemicals and those that pass water through an electric or magnetic field. The calcium salts, if viewed through a microscope, appear star-shaped, and it is in this form that they can bind together.

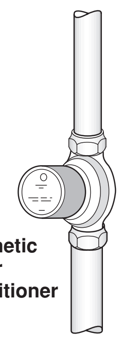
Chemical water conditioners use polyphosphonate crystals. These dissolve in the cold water and bind to the star-shaped salts, making them circular. These polyphosphonate crystals are placed in the storage cistern or into specially designed containers fitted into the pipeline. Periodically the crystals must be replaced.

Electronic and magnetic water conditioners are devices fitted in the pipeline which pass a low current of a few milliamperes of electricity across the flow of water. This tends to alter the structure of the hard salts, making them more round or solid in shape and therefore they do not stick together but should pass through the system. Electronic and magnetic water conditioners should be installed as close as possible to the incoming main supply. Some types of electronic conditioners are plugged into the mains electric supply, whereas others rely on the current produced by electrolysis.

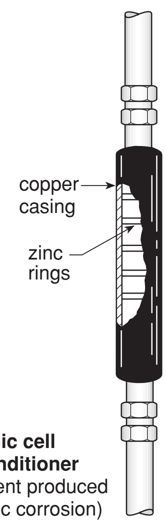


Base exchange water softener
(complete removal of calcium salts)

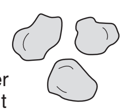
Magnetic and chemical water conditioners



magnetic water conditioner

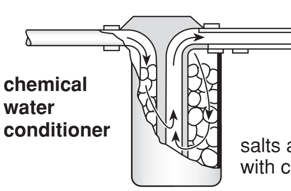


galvanic cell water conditioner
(electric current produced by electrolytic corrosion)

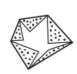


salts after treatment with electronic current

calcium carbonate binding together in untreated water, as viewed through a microscope



chemical water conditioner



salts after treatment with chemicals

Water treatment

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Boosted Water Supplies

Relevant British Standards
BS EN 806-2 and BS 6700

There are two reasons why water may need to be boosted: (1) to give a better flow and pressure at the draw-off point in a domestic situation (see page 118, Connections to Hot and Cold Pipework); or (2) as a method of raising the water supply in high-rise buildings above the height that the mains will supply.

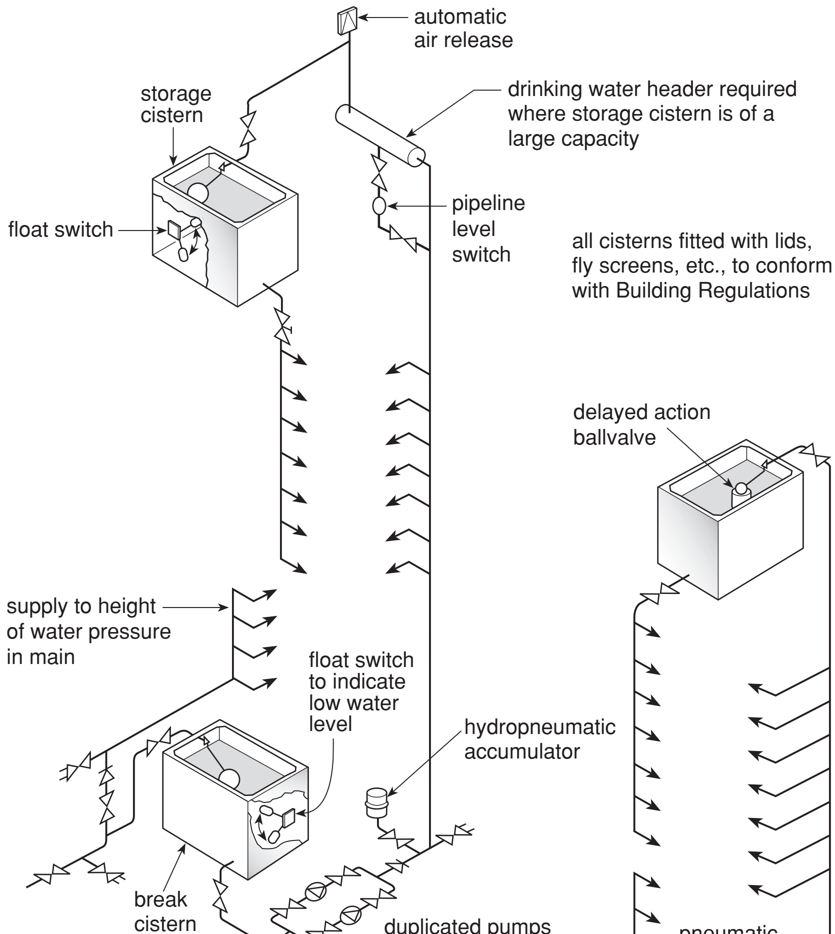
The pumps are usually fitted indirectly to the supply main. If fitted directly, a serious drop in the mains pressure may occur when the pumps are running. The indirect system consists of a suitably sized break cistern located at the inlet to the pumping set (see figure). Nowadays, 'packaged' pumping sets are installed consisting of dual pumps to overcome the problem of failure of (or the need to renew) one of the pumps. The second pump also assists at times of high demand on the system, cutting in as necessary. To prevent pump seizure and stagnation of water, the pumps should be designed to work alternately. Two types of system will be found: those using pressure-sensing devices and those using float switches.

Pressure-sensing devices These include transducers or pressure switches which sense the drop in pressure in the pipeline. These come fitted to, and form part of, the packaged pumping set. To prevent the continuous cutting in and out of the pumps, a delayed action ballvalve or float switch is used in the high level cisterns. If draw-off points are required on the riser, a pressurised pneumatic storage vessel is sometimes incorporated to prevent the continual cutting in and out of the pumps; this consists of a vessel containing a rubber bag surrounded by a charge of air. When the pumps are running, water can enter and fill the bag, taking up volume and compressing the air. When the pumps are turned off, the compressed air forces the water back out into the pipeline, as and when required.

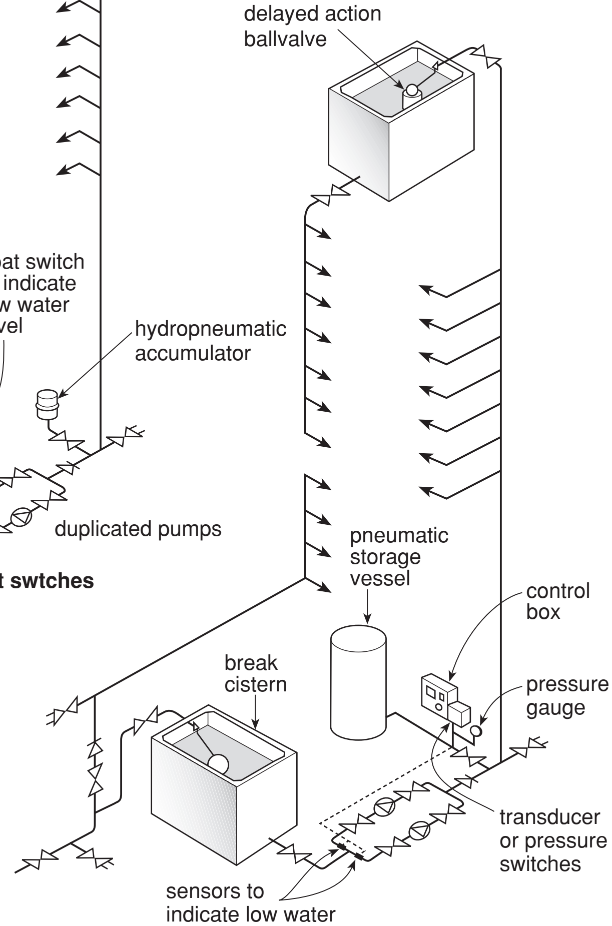
Float switches These are devices which rise and fall with the water level. They are therefore located in cisterns or pipelines to sense a drop or lack of water within the system. If the high level cistern is of large capacity, it may be necessary to have a drinking water header to prevent stagnation, or a separate high level cistern for drinking water purposes.

To prevent the pumps running dry for any reason, a sensing device needs to be incorporated in the pipe feeding the pumps, e.g. an in-line sensor or a float switch fitted in the break cistern.

Water hammer can be a problem when fitting pumps to any system. Therefore a hydropneumatic accumulator should be incorporated if necessary. Packaged pumping sets incorporate these as standard. They are basically small pressurised pneumatic vessels, the air taking up the shock wave (for example see page 129).



Pumping set using float swtches



Pumping set using pressure sensing devices

Typical packaged pumping set

Boosted water supplies

Fire-fighting Systems

Relevant British Standards
BS 4422 and BS 5306

Sprinkler systems

On the outbreak of fire, a sprinkler system causes an automatic discharge of water to be sprayed, usually from sprinkler heads located near the ceiling. See the figure opposite for a typical arrangement for the pipe layout. See also page 98, Domestic sprinkler systems. In commercial premises, as distinguished below, there are two basic designs:

- The *wet-pipe system,* in which the sprinkler system is permanently charged with water.
- The *dry-pipe system,* in which the sprinkler system is charged with compressed air and is used in unheated buildings where the temperature may fall below 0°C. If they were to be charged with water these pipes would be liable to freeze.

The operating principle of a sprinkler head is that when the temperature around the head rises to a predetermined level, either a water filled glass bulb breaks, or a solder strut melts, allowing the valve to fall and open.

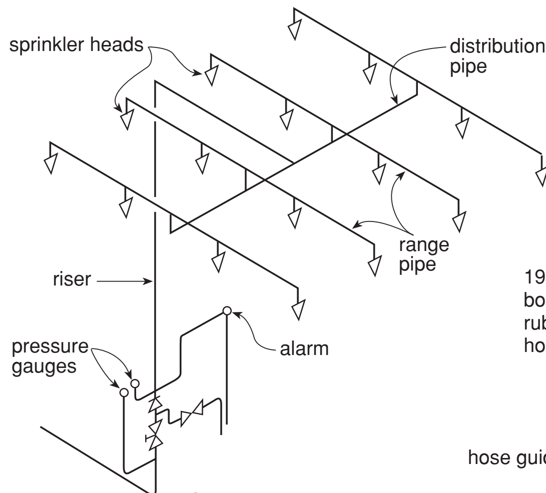
Hose reel systems

When hose reels are used, they should be sited in prominent positions adjacent to exits, so that the hose can be taken to within 6 metres of any fire. Two basic designs of hose reels are available: those which automatically turn on as the hose is reeled out, and those which need to be turned on at the wall. For the latter type, a notice must be provided near the reel indicating the need to turn on the supply. The hose reel must be adequate to supply a minimum of 0.4 litres per second.

The water supplies feeding sprinkler systems and hose reels need to be adequate (see particularly BS 5306); they are usually maintained via a system of boosted water supply.

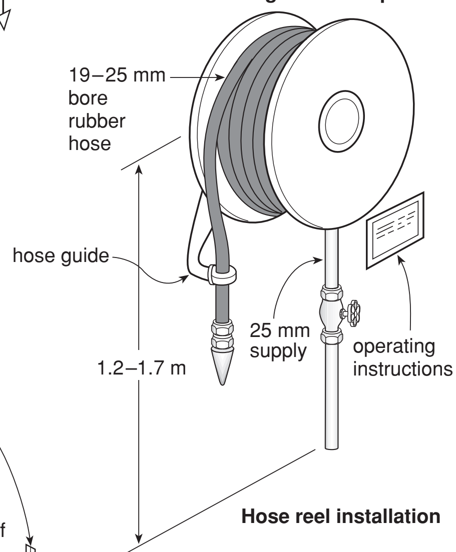
Wet and dry risers

These systems are for the use of the fire brigade and consist of pipes, (100–150 mm in diameter) running up the building with one or two fire brigade hydrants on each floor. The purpose of this pipe is to save time running canvas hoses up the staircases should the building be on fire. The dry pipe system is used in buildings up to 60 metres in height (20 storeys) and is fitted with an inlet at ground level for the fire brigade to connect to the nearest hydrant. The wet riser is used in taller buildings because the mains pressure would be insufficient to rise to such great heights, and is charged with water under pressure by a booster pump capable of delivering 23 litres/s. The water pressure supplied to the hydrants should not exceed 690 kN/m^2, otherwise damage may occur to the hose. Therefore, a pressure relief valve is fitted at the hydrant; this opens if the pressure is too great, the discharging water returning to the break cistern.

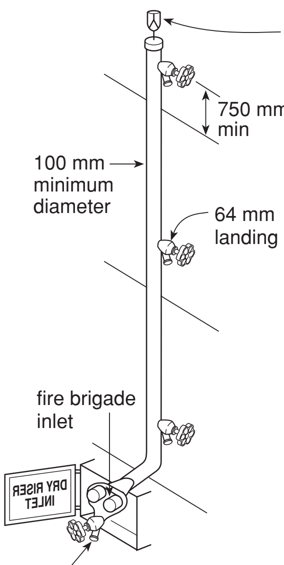
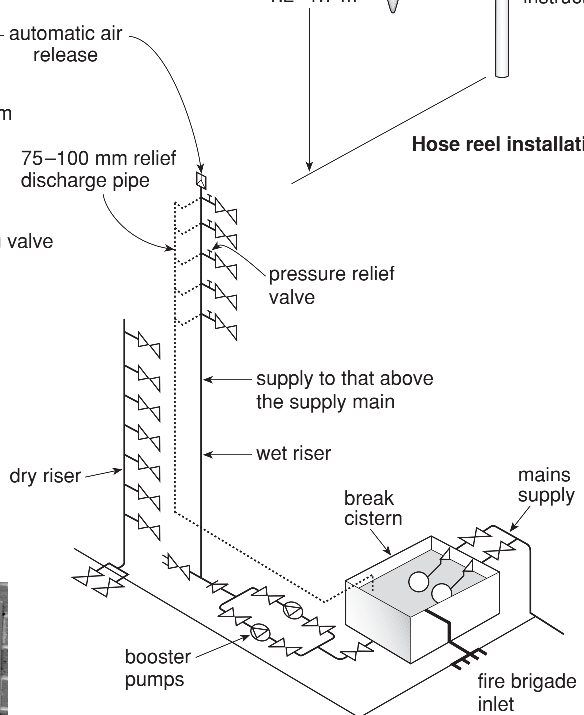


Sprinkler system

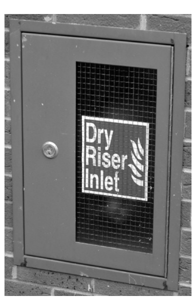
Fusible link and glass bulb sprinkler heads



Hose reel installation

Wet and dry risers



Dry riser inlet

Fire-fighting systems

Domestic Sprinkler Systems

Domestic sprinkler systems are relatively rare in the UK, but are becoming more and more sought after as a means of protection in the event of a fire. Used in conjunction with a smoke detector they are said to provide 98% protection. Should a fire break out in the home, the longer it burns undetected the more dangerous it becomes. Most people who discover a fire in the home do so too late and as a result many are trapped. The installation of a domestic sprinkler system should only be undertaken by an operative who has completed a recognised training course in design and installation. Water damage will clearly result from the activation of a sprinkler head, however it is approximately one hundred times less damage than could be expected from the fire services at a well-established fire. When considering the installation of a sprinkler system the local fire authority, water company and the fire insurer should be consulted.

Water supplies

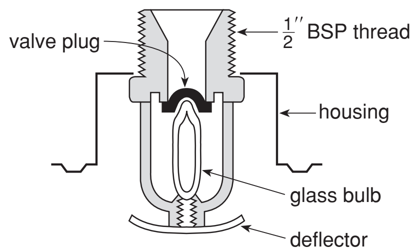
One of the first things to consider is the water supply pressure and flow. It is vital that sufficient flow and pressure are available at the sprinkler head at all times, both uninterrupted and reliable. Failure to meet these basic requirements would mean the system is unsuitable. Good water flow is essential to meet the needs of cooling the combustible materials below their ignition temperature and a good pressure is needed to create an effective water spray for the sprinkler head. The water supply needs to maintain the manufacturer's required flow and pressure when discharging through two sprinkler heads at the same time. At least 60 L/min is required through any single sprinkler head, and 42 L/min through any two sprinklers operating at the same time. This would usually require the incoming supply pipe to be at least 25 mm nominal internal diameter. The water may be provided from a direct mains connection providing there is sufficient supply to provide both the domestic water and sprinkler system together plus an additional flow rate of 50 L/min. It is possible to have a system that incorporates a **demand valve** that closes off the domestic water supply should the sprinkler system be activated. Alternatively, a separate dedicated water supply would be needed for the sprinkler system. This could be via a second mains connection or by the use of a stored water supply. Where a stored supply is selected there must be sufficient storage to provide the minimum recommended flow and pressure by the sprinkler head manufacturer for a period of at least 10 minutes.

Sprinkler heads

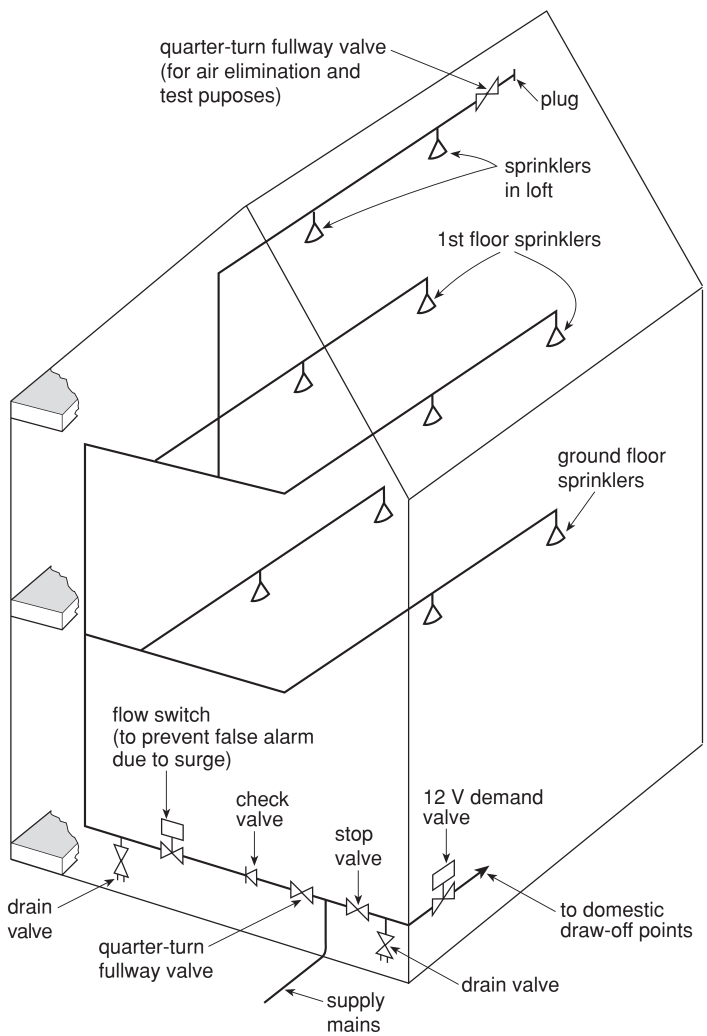
These need to be of a design that is suitable for residential use. They need to be installed throughout all the habitable parts of the dwelling, each head covering not more than 12 m^2. The sizes available give a nominal diameter at the orifice outlet of between 10 and 20 mm. The temperature ratings for individual heads is given in the table opposite; the head selected should allow for 30°C above highest anticipated ambient temperature.

Sprinkler temperature ratings

Sprinkler type	Temperature range (°C)	Colour code
Fusible link	55–77	None
	80–107	White
Glass bulb	57	Orange
	68	Red
	79	Yellow
	93	Green



Typical glass bulb sprinkler head



Domestic sprinkler system

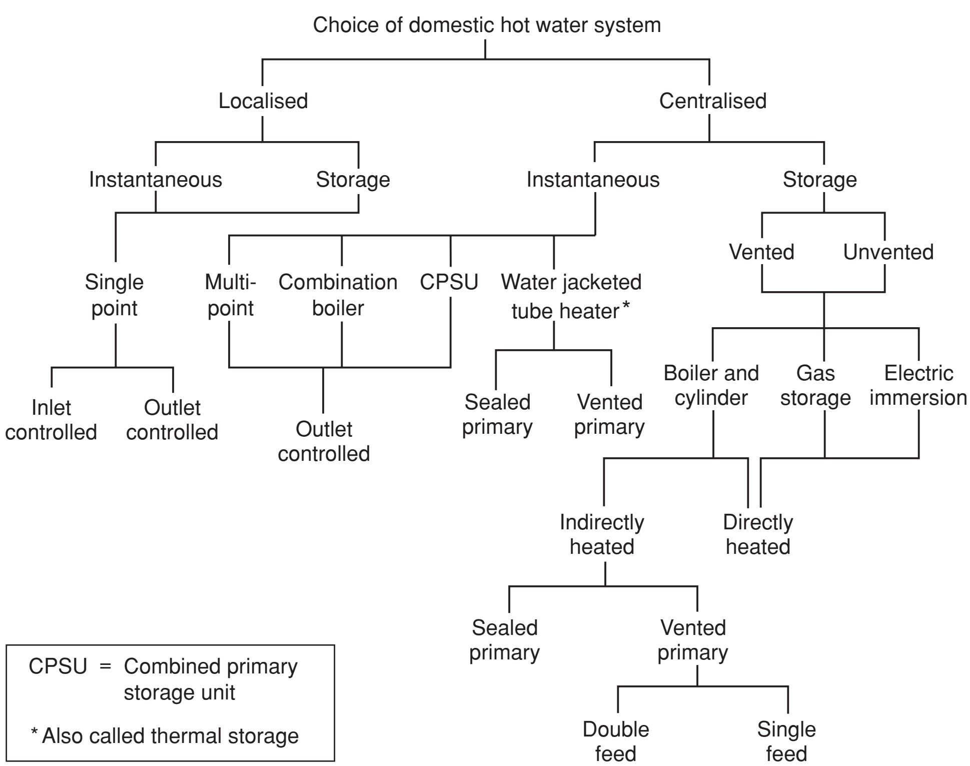
Hot Water Systems (Design Considerations)

Relevant British Standards
BS EN 806-2 and BS 6700

When a supply of domestic hot water (dhw) is required, the designer has to consider many factors to ensure the most suitable system for the building in question.

The diagram below gives a brief guide to the system designs which are available. Generally, dhw systems can be divided into centralised and localised. The terms *instantaneous* and *storage* simply indicate whether the water is heated only as required (instantly) or to a temperature indicated by a thermostat and held in a vessel until required (stored).

A **centralised system** is one in which the water is heated and possibly stored centrally within the building, supplying a system of pipework to the various draw-off points.



CPSU = Combined primary storage unit

* Also called thermal storage

A **localised system** is one in which the water is heated locally to its needs, e.g. a single-point heater located above a sink. It may be chosen where a long distribution pipe would mean an unnecessarily long wait for hot water to be drawn off at the appliance.

In a centralised system, the water may be heated in the hot storage vessel itself, or it may be heated in a boiler or small gas circulator located in a more convenient position. Should this be the case, the water is fed to and from the boiler by what are known as primary flow and return pipes. The circulation of water can be achieved by *convection currents* being set up in the flow and return pipework, or by the use of a circulating pump. Water flows by convection currents as a result of expanding in volume when heated; modern systems utilising gas or oil boilers would require a pumped circulation system.

When water is heated it becomes less dense than cooler water. Because hot water rises, it is drawn off from the top of the storage vessel to supply the various draw-off points (taps). The cold feed is supplied low down in the vessel, thus preventing unnecessary cooling to the previously heated water. At the highest point in the system, a vent pipe is run up to terminate, with an open end just below the feed cistern lid. This pipe is to allow air to escape from the system upon initial filling and allows air in on draining down.

The vent pipe also acts as a fail-safe device should the cold feed become blocked, preventing the expanding water passing back up into the cistern. Should this occur, the water is forced over the vent and discharges into the cistern. The height to which a vent pipe is to rise above the water level in the cold cistern is found by allowing 40 mm for every 1m head of water in the system, plus an additional 150 mm. For example, if the distance between the lowest point in the system and the water level in a cistern is 5 m, the vent pipe should be carried up above the water level by a minimum distance of: $5 \times 40 + 150 = 350$ mm.

The temperature at which the water is stored in the cylinder should not exceed 60°C. Failure to observe this limit may result in the user being scalded and scale build-up in hard water districts. Storage temperatures below 60°C are concerning as the Legionella bacteria survival time increases as the temperature drops below 60°C. At 60°C the bacteria is killed within a few minutes. Some means of controlling the temperature should therefore be provided. When a primary circuit is used with an independent boiler, the temperature is generally controlled by a cylinder thermostat positioned a third of the way up the base of the dhw cylinder operating a motorised valve; however, for older systems the water temperature may be controlled by a boiler thermostat or a thermostatic control valve located on the return pipe.

These last two temperature control methods would no longer comply with the Building Regulations where an oil or gas boiler is installed.

Direct Hot Water Supply (Centralised)

Relevant British Standards
BS EN 806-2, BS 5546 and BS 6700

Various fuels and systems of design can be used to heat the water in a centralised direct hot water system, including the following:

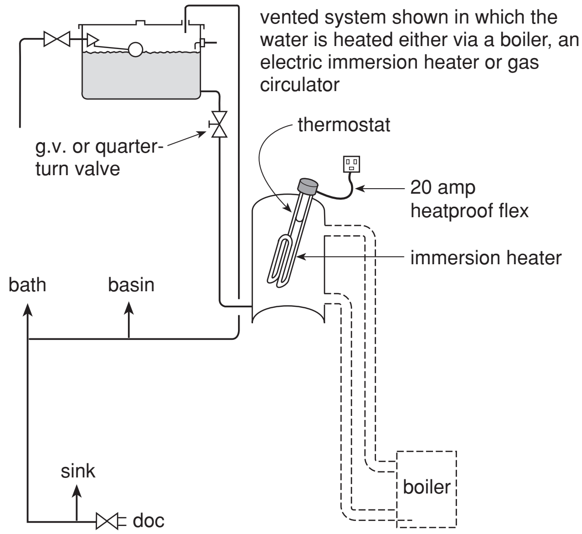
Electric water heating A system which uses an immersion heater installed in the hot water storage vessel. This behaves in a similar way to the element in an electric kettle: when the desired temperature is achieved, sensed by a thermostat, the element is switched off. It is essential that the heater element extends to near the bottom of the storage vessel because it will not heat the water below it. The heater should be at least 50 mm from the base of the storage vessel to prevent convection currents disturbing any sediment. Sometimes two heater elements are used, one fitted at low level and one much nearer the top. The higher immersion heater is switched on if, for example, only enough hot water is required to fill a sink, whereas should enough hot water to fill a bath be required, the lower heater is switched on.

The electrical power supply to an immersion heater must come directly from the consumer unit (see page 284) to terminate close to the hot storage vessel with a double pole switch. It is from here that a 21 A heat-proof flex is run to the heater.

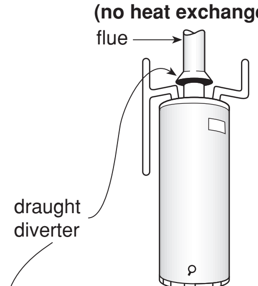
Gas storage heaters Purpose-made vessels which have gas burners installed directly below the stored water. The system incorporates an open flue which must be discharged to the external environment, the flue passing up through the storage cylinder.

Boiler-cylinder system A system in which a small boiler (e.g. a gas circulator) is located somewhere in the building and the hot water is conveyed via primary flow and return pipes. When using this system to heat the dhw, it is not possible to include radiators on the primary pipework, unless they are made of non-ferrous metals. This is because the water which passes to the boiler is being supplied by the feed cistern and is constantly passing through the pipework as it is drawn off at the taps, thus bringing in entrapped gases which will cause atmospheric corrosion to ferrous metals. Direct systems which use primary flow and return pipes should not be used in hard water areas because scale build-up in the pipework will block the flow.

Instantaneous systems It is possible to heat the water directly by passing it through a heat exchanger. Several systems are available, e.g. the Multi-point, the water-jacketed tube heater, the combination boiler and the combined primary storage unit. The main disadvantage with instantaneous heaters is that only a limited number of draw-off points can be supplied at once, because of the restricted flow rate through the heat exchanger.

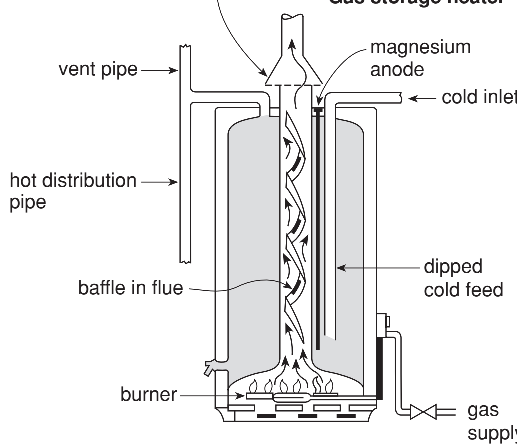


Direct dhw cylinder (no heat exchanger coil)

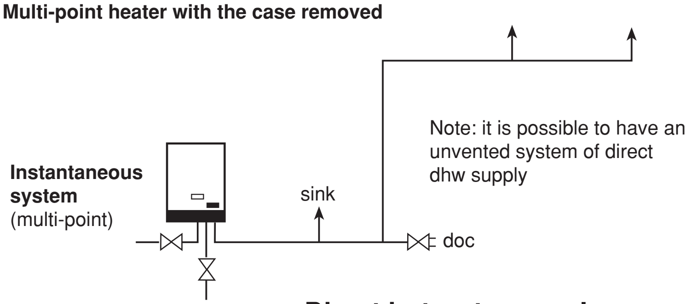


Gas storage heater

Multi-point heater with the case removed



Section through gas storage heater



Direct hot water supply

Indirect Hot Water Supply

Relevant British Standards
BS EN 806-2, BS 5546 and BS 6700

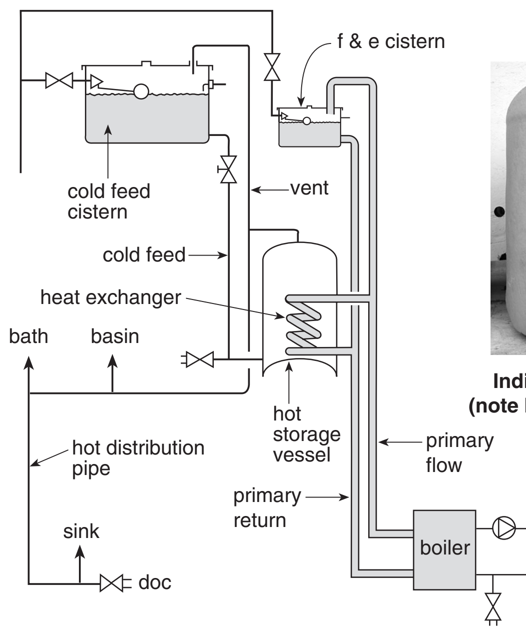
The indirect dhw system is probably the most common form of dhw and allows a boiler to be used for central heating purposes also. The storage vessel is the heart of these systems and consists of a special cylinder in which is fitted a heat exchanger. The heat exchanger allows water from the boiler circulating in the primary pipework to pass through, but not mix with, the water in the cylinder itself. Thus, in effect, it really consists of two systems which appear to join at the hot storage vessel.

Water is heated in the boiler and conveyed to the hot storage vessel via primary flow and return pipes by the use of a circulating pump; older systems utilised gravity circulation (convection currents). The water supplying this primary circuit can be taken from the f & e cistern, which is usually located in the roof space, or directly from the supply main in the case of a sealed system (see Part 3, Central Heating). The water, once in the primary pipework, is never changed except for maintenance purposes. Therefore, any calcium carbonate (limescale) will have been precipitated and any gases which came in with the fresh supply will have escaped from the water. Thus, the water in this state is somewhat neutralised; it will not cause excessive corrosion of steel radiators and is suitable for central heating purposes.

Because the primary water must not be changed, the water supply for domestic purposes needs to be taken from a separate supply, and, if using a feed cistern in the roof space, it must be separate from the f & e cistern to prevent mixing of the waters in each system.

As we have seen, most indirect systems are of the double feed design, using two cisterns in the roof space, and having a coil or annulus type heat exchanger fitted into the cylinder. But there is a second older type, known as a single feed indirect system (the design in the figure opposite being known as the Primatic). This system used a specially designed heat exchanger which allowed the primary circuit to fill up via a built-in feed pipe. In so doing it maintained an air break separating the primary and secondary waters.

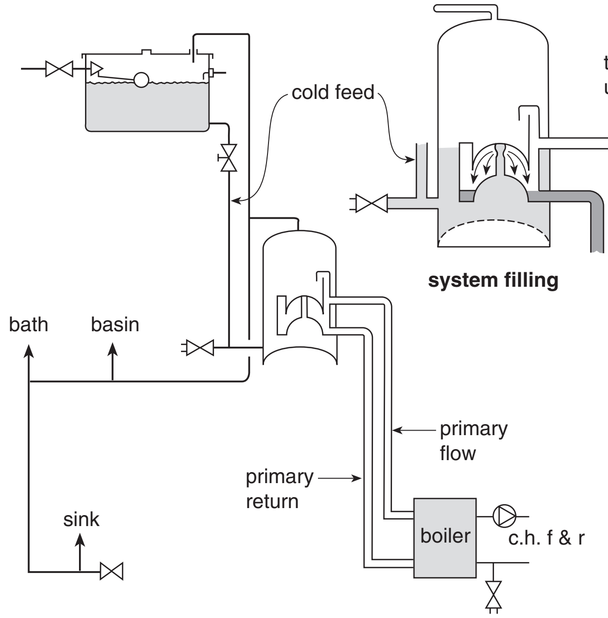
The figure shows how the expansion of the water in the primary circuit is taken up by moving the air in the top dome back through its cold feed pipe to the lower dome. The primary circulation system must not be too large (having many radiators) because the excessive quantity of water that the system will contain would, when expanding, exceed that of the space available in the dome, thus forcing the air out. Also, a circulating pump must not be used on the primary circuit to the dhw cylinder for the same reason. Should the air be lost, the space would be filled instead with water and it would be converted, in effect, into a direct system of hot water supply; this would give rise to corrosion problems.



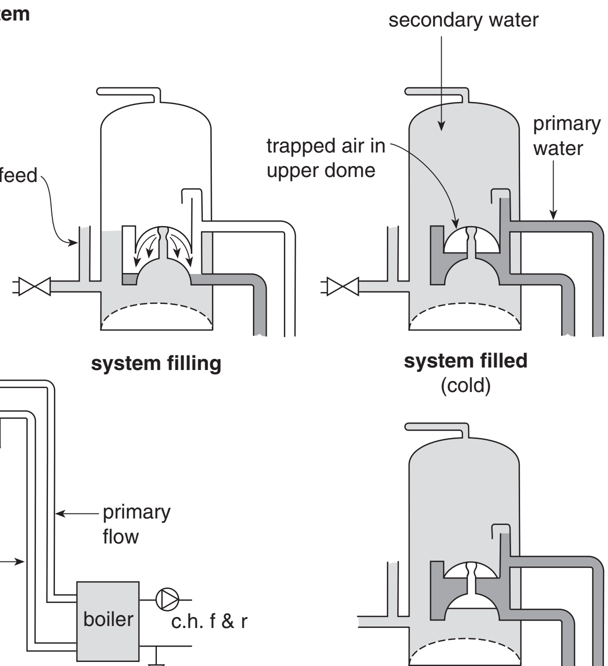
Vented double feed indirect system of hot water supply

Indirect dhw cylinder (note heat exchanger coil)

Single feed cylinder



Vented single feed indirect system of hot water supply



system filling

system filled (cold)

system once heated

The expansion of the primary water is taken up by forcing the air from the upper dome to the lower dome

Indirect hot water supply

Unvented Domestic Hot Water Supply

Relevant British Standards
BS EN 806-2 and BS 6700

When considering the installation of a system of unvented dhw (stored supply in excess of 15 litres), Part G of the Building Regulations should be observed. This identifies several requirements to be met by the local authority. Systems must be installed by an 'approved' installer who is registered with a recognised body and the system must be purchased as a *unit* or *package*. From April 2006, systems installed need to be self-certificated in order to meet the requirement of Part G.

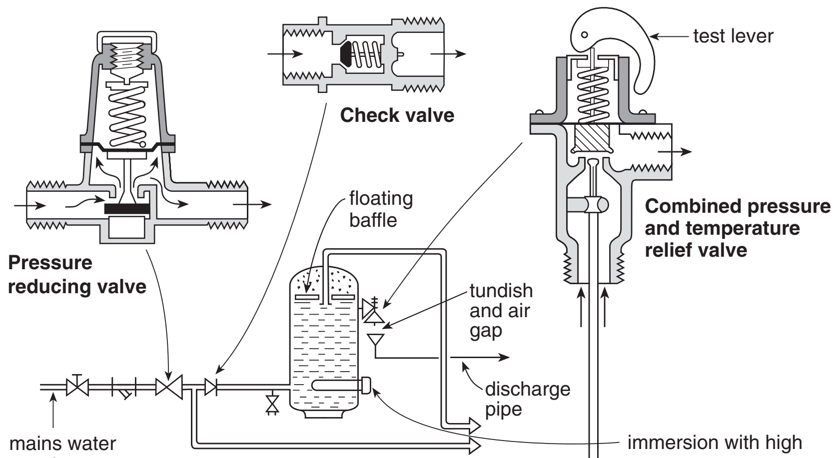
A *unit* is a system in which all the component parts have been fitted by the manufacturer at the factory. A *package* is a system in which the temperature-activated controls are incorporated but all other components are fitted by the installer. In both cases this ensures that the safety devices, which are 'factory set', are installed with the system. The Regulations state that at no time must the water reach 100°C, which is ensured by the use of three safety devices: the thermostat (operating at 60°C); a high temperature thermal cut-out device (which locks out at 90°C); and a temperature relief valve (designed to open at 95°C).

With unvented systems the water is taken directly from the mains water supply. There is no open vent pipe or storage cistern where the expansion of heated water can be taken up. Therefore some form of expansion vessel needs to be incorporated. To comply with water regulations, a check-valve must be fitted on the supply pipe to prevent a backflow of hot water down the supply main. Should the expansion vessel not function for any reason, the water, on expanding, will be forced out of the pressure relief valve.

Any water discharging from either a temperature relief valve or pressure relief valve must be conveyed, via an air break, to a suitable discharge position. The discharge pipe must not exceed 9 m in length and the pipe diameter of the discharge outlet must be maintained. A pressure-reducing valve is fitted as a precaution to reduce excessive water pressures which may cause damage to the system. In order to ensure equal pressures at both hot and cold draw-off points, the cold supply pipe is sometimes branched off after this valve.

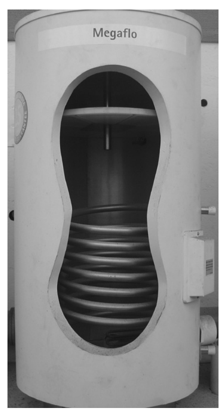
The advantages of these systems are the higher pressures obtainable at the draw-off points, the use of less pipework and the fact that less time is required for installation. The disadvantages are frequently overlooked. First, such a system can only be installed should the flow rate (volume of water) be sufficient to supply both hot and cold water at once, bearing in mind that several appliances could be running at the same time. Second, in hard water districts, the build up of scale around temperature and pressure relief valves could make those valves ineffective. Regular servicing of the system is therefore essential.

Some unvented dhw cylinders use a sealed expansion vessel to take up the expanding water. Others incorporate an inverted dome which traps a pocket of air, thus doing away with the need for a sealed expansion vessel. Unfortunately, high water turbulence within the cylinder sometimes causes the air trap to be lost, although one manufacturer has overcome this problem by using a floating baffle to cut down on turbulence. After a period of time the air may be absorbed into the water rendering the dome ineffective, resulting in the pressure relief valve opening. Consequently the cylinder will need draining down to recharge the dome with air.

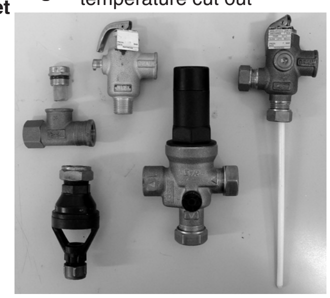


Unvented system incorporating an air pocket

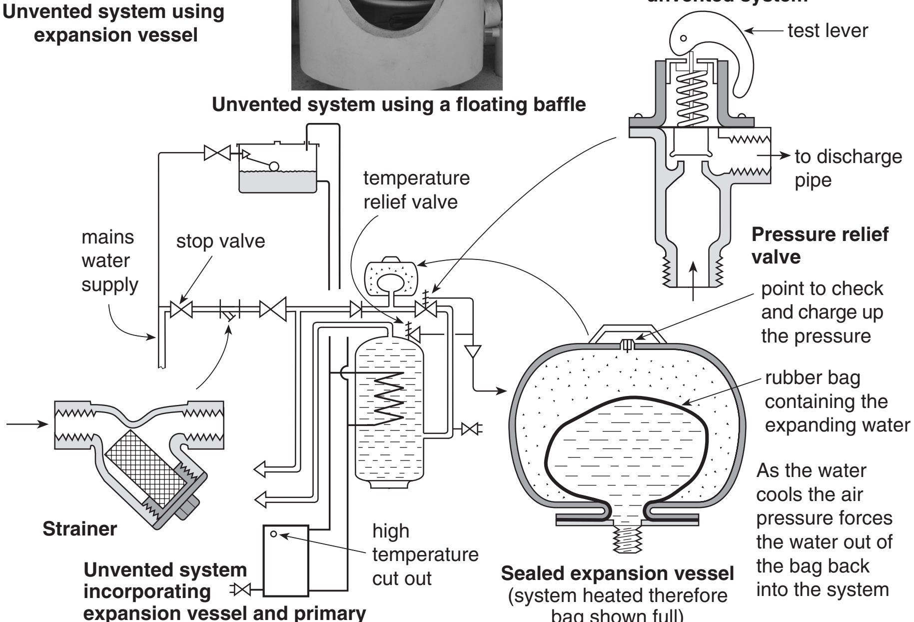
Unvented system using
expansion vessel



Unvented system using a floating baffle



Selection of control valves found on
unvented system



Unvented domestic hot water supply

Hot Distribution Pipework

Relevant British Standards
BS EN 806-2 and BS 6700

The hot water in the storage vessel needs to be preserved for as long as possible to save on fuel consumption. The cylinder and pipework should therefore be insulated. However, hot water can also be lost due to the circulatory flow of hot water, by convection currents, up the vertical vent pipe. To prevent this, the hot distribution should be run a minimum of 450 mm horizontally on leaving the top of the hot storage vessel.

When a tap is opened, before the hot water can discharge from the spout, the cold water in the pipe has to be drawn off and is invariably allowed to run to waste. This also causes a certain amount of inconvenience to the user. Where possible the system should be designed to provide a temperature of no less than 50°C within 30s, although this may not be achievable where instantaneous or combination boilers are used. The run of pipe to the appliance is referred to as a 'dead leg' and should, where possible, not exceed that indicated in the following table.

Maximum length of uninsulated hot distribution pipe

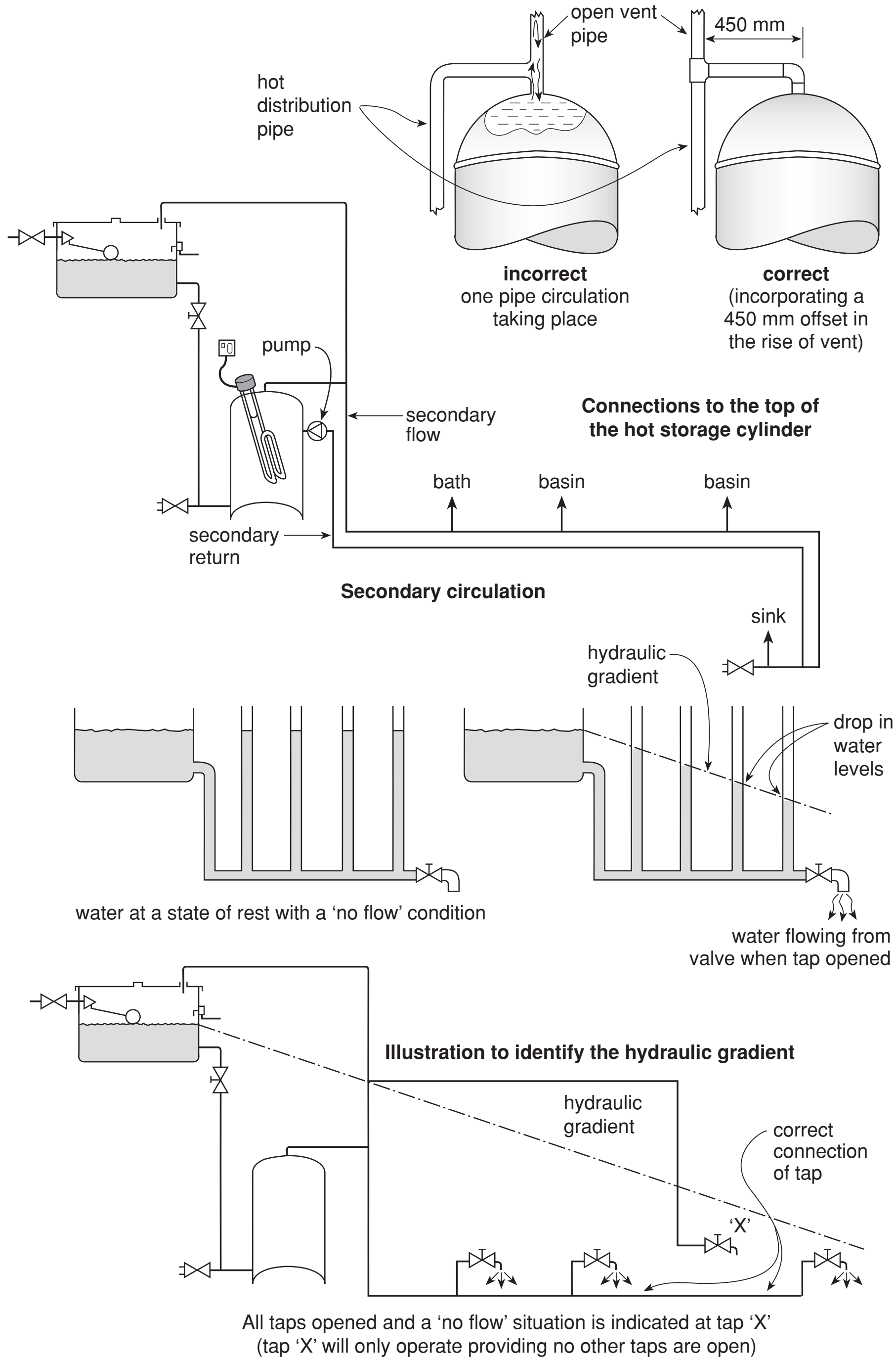
Internal bore of pipe (mm)	Length (m)
less than 10	20
11–19	12
20–25	8
Over 26	3

Where it is not possible to keep within these limits, the pipe should be thermally insulated, or some other method should be used to ensure that the hot water appears quickly at the tap. Either of two methods can be adopted to meet this requirement: a specially designed heat tracing tape can be used, which heats up as necessary, maintaining the water temperature; or a system of secondary circulation will need to be installed.

Secondary circulation An arrangement in which a pipe is run back to the dhw cylinder from the furthest point on the distribution, thus forming a circuit. Water can flow around this circuit usually by the use of a non-corrosive circulating pump, thus allowing hot water to be kept close to the draw-off points. The return pipe is connected within the top third of the cylinder to prevent the cooler water, lower down the cylinder, mixing with the hot water and reducing its temperature.

Hydraulic gradient When a tap is opened and water drawn from the system, the water level in any vertical pipe will drop. The amount by which it drops will depend on the size of the pipework and the flow rate being drawn off (see figure). In any cistern-fed system, be it hot or cold, if the pipework is less than perfect, when several appliances are running at once, one will be starved of water (usually the highest draw-off point). This is due to the above-mentioned drop in water level in the vertical pipe.

When installing a system of hot water supply, it is particularly important to consider this design concept, because any high connections in the vertical rise of the vent pipe will be starved of water unnecessarily.



Hot distribution pipework

Heat Recovery Period

This is the amount of time required to heat up a quantity of water. The recovery time varies, depending upon the power rating of the heat source used, but basically the higher the power rating, the shorter the heating up period of the water. Power of heat source and the heat recovery period are related by the following formula:

$$\text{Power} = \frac{\text{SHC} \times \text{kg} \times \text{temperature rise}}{\text{time in seconds}}$$

$$\text{SHC} = \text{specific heat capacity of water } (= 4.186\,\text{kJ/(kg k)})$$

$$\text{kg} = \text{the mass of water to be heated (mass of 1 litre} = 1\,\text{kg)}$$

Example: Find the power required to heat 100 litres of water in $2^1/_2$ h from 4°C to 60°C.

$$\text{Power} = \frac{\text{SHC} \times \text{kg} \times \text{temp rise}}{\text{seconds in } 2\frac{1}{2}\text{ h}} = \frac{4.186 \times 100 \times 56}{9000} = 2.6\,\text{kW}$$

Note that the above example does not allow for heat loss and for the heating up of the hot storage vessel itself. It would be advisable to add, say, 10% for this; thus 2.6 + 10% = 2.86 kW, and as a result a 3 kW heater would be chosen.

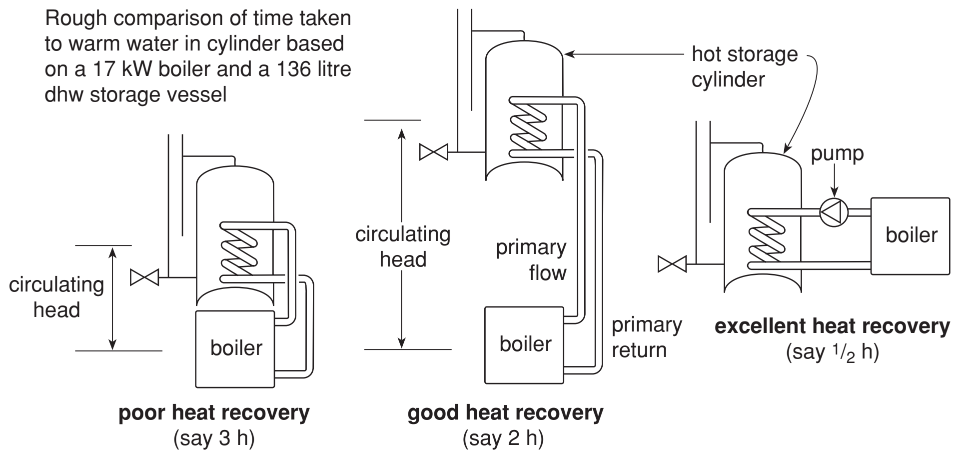
It will be seen that as the incoming temperature of the water has a bearing upon the recovery time, one can only estimate its value. Often the householder will require some guidance concerning the time it will take to heat the water using an existing immersion heater. This is also found using the above formula, although it will need transposing to suit this new situation, to give:

$$\text{Time (seconds)} = \frac{\text{SHC} \times \text{kg} \times \text{temp rise}}{\text{power (kW)}}$$

Example: Find out how long it will take to increase the temperature of 136 litres of water from 10°C to 60°C, using a 3 kW immersion heater. Ignore heat losses, etc.

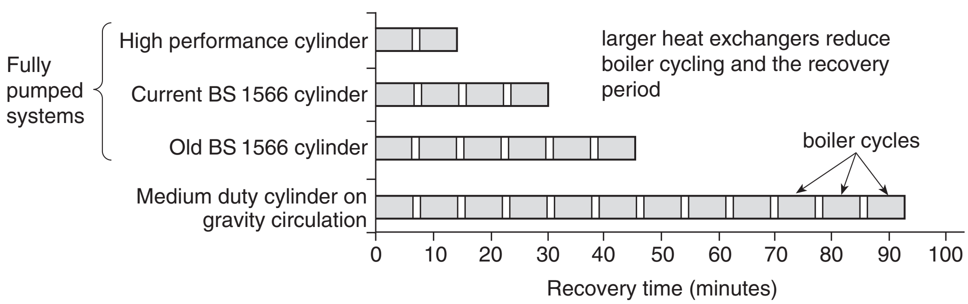
$$\text{Time} = \frac{4.186 \times 136 \times 50}{3} = 9488\text{s or } 2.6\,\text{h (2 h 36 min)}$$

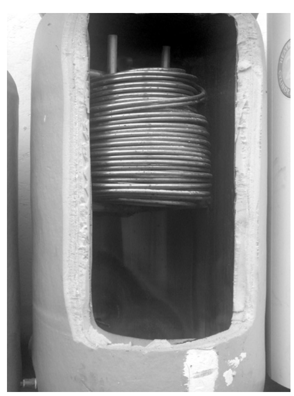
Where the water is heated in a boiler, etc., away from the hot storage vessel, it will need to be conveyed via primary flow and return pipework. Circulating this water to and from the storage vessel can be achieved by gravity circulation or speeded up by the use of a circulating pump (see page 148, Fully Pumped System). The greater the circulation pressure from the heat source to the storage vessel, the shorter will be the heat recovery period. Where gravity circulation is chosen to convey the hot water, it should be understood that the greater the circulating head, the greater will be the circulating pressure. Where only a poor- or low-circulating head can be achieved, larger pipe sizes or the inclusion of a circulating pump will be required. It must be noted that for gas or oil installations gravity circulation is no longer permitted in the design of the system.



Heat recovery period

The heat recovery period is also influenced by the design and dhw cylinder used. All modern systems use BS 1566 cylinders. These have no less than 5–6 turns within the heat exchanger coil and the cylinder includes factory-fitted insulation foam. High performance cylinders can also be purchased with an even greater number of coils. The following chart shows the number of boiler cycles and approximate time required to raise a typical 136 litre cylinder up to the required temperature.





High performance cylinder
(note the many coils to provide rapid heat recovery)

Instantaneous Domestic Hot Water Supplies (Centralised)

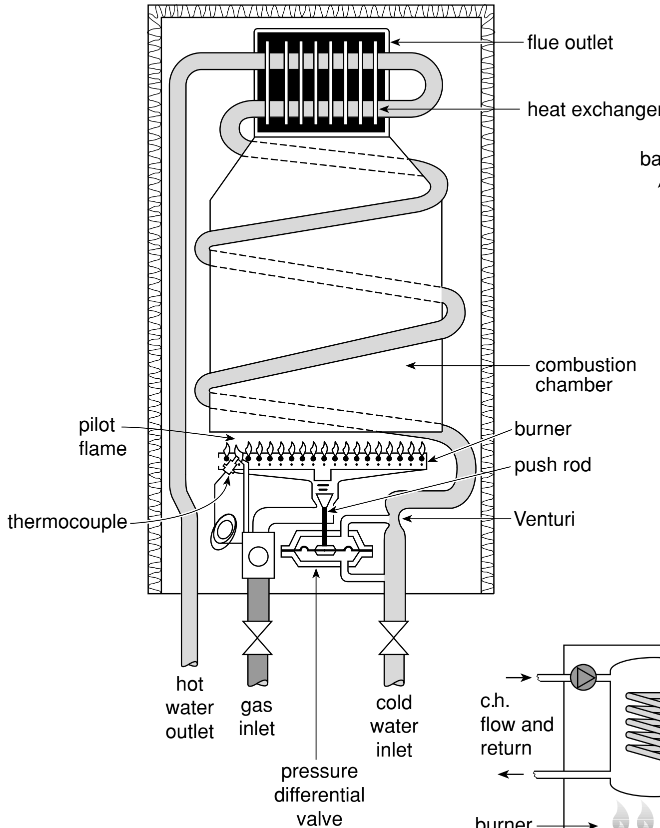
Relevant British Standards
BS EN 806-2, BS 5546 and BS 6700

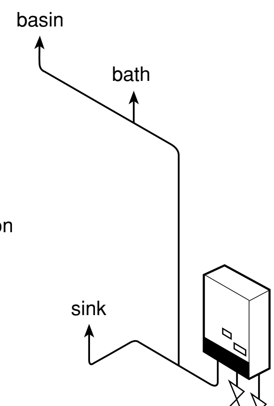
With instantaneous dhw systems, the principle is to pass the cold water through a heat exchanger, such as a coil of pipework passing through a heat source, which heats the water by the time it comes out the other end. There is a limit to the speed at which the water can be heated; therefore, the flow rate (volume) of water needs to be minimised; failure to minimise the flow rate will result in an insufficient heat-up. Because of this reduced flow rate of water passing through the heat exchanger it is not possible to supply several outlets at once; as a result these systems are unsuitable where there is to be high demand for hot water. With these systems you only heat the water as and when it is required; therefore, a saving can be made in fuel consumption. Instantaneous heaters include multi-points, water-jacketed tube heaters, CPSUs and combination boilers. (See page 154 for combination boilers.)

The multi-point This consists of a gas burner located beneath a heat exchanger. When hot water is required, the water, in passing through the heater, causes the gas valve to open, and this is ignited by a pilot flame. The gas valve opens as the result of a reduction in the water pressure on one side of a diaphragm in the pressure differential valve caused by water passing through a Venturi. Attached to the diaphragm is the push rod which opens the gas line. On shutting the water supply, the pressure in the differential valve equalises and the diaphragm is sprung shut, closing off the gas supply.

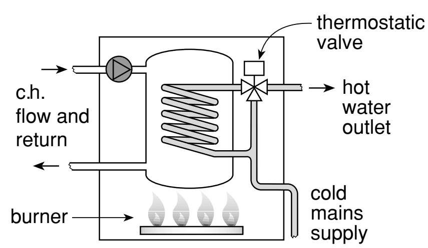
The water-jacketed tube heater Sometimes referred to as a thermal storage system, this is a system in which the water to be heated is passed through a stored supply of central heating water. It is like an indirect system of dhw in reverse; the domestic water flows through the heat exchanger and not the primary water. One end is connected to the cold supply main, the other directly to the taps. When the water is heated, a small amount of expansion occurs and is taken up in a small expansion vessel located in the cold supply line fitted to the unit or within the unit itself via an expansion chamber. Because the water in the heat exchanger can potentially become as hot as the water in the primary storage cylinder, it must be noted that water, upon leaving the unit, passes through a thermostatic mixing valve in which the water is cooled from the cold supply to give a temperature no hotter than 60°C.

The combined primary storage unit (CPSU) This system of instantaneous dhw is the same as a water-jacketed tube heater, the only difference being that everything is contained within the boiler and no separate hot water storage vessel is required.

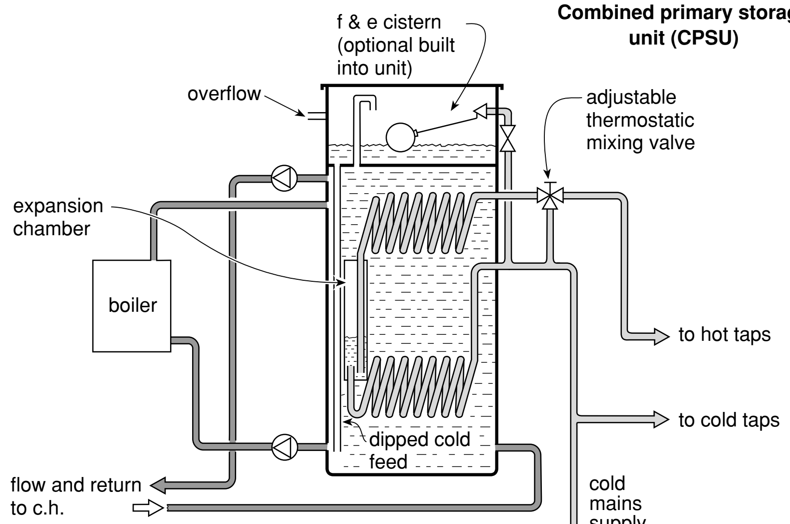




Gas multi-point



Combined primary storage unit (CPSU)



Water jacketed tube heater

Instantaneous domestic hot water supplies

Localised Hot Water Heaters

Relevant British Standards
BS EN 806-2, BS 5546 and BS 6700

Two distinct types of localised dhw heaters will be found: the instantaneous and storage types. In each case the heater will serve only one sink, or two if fitted in close proximity to the heater.

Instantaneous single points

These heaters are fuelled either by gas or electricity and heat the water only when required. They are usually fitted with a swivel spout and located directly above the sanitary appliance, the water flow usually being inlet controlled. The gas heater works on the same principle as the multi-point (see page 112).

With electric instantaneous heaters, the water is allowed to flow into the heater, where it is surrounded by an electric heating element. Because of the small volume of water surrounding the element, the water quickly heats up as it is drawn through the heater. The temperature of the water will be directly related to the power rating of the appliance and the water flow rate. The water flowing through the heater is sensed by the pressure or flow switch located on the inlet supply, which in turn makes the electrical contacts to the immersion heater element.

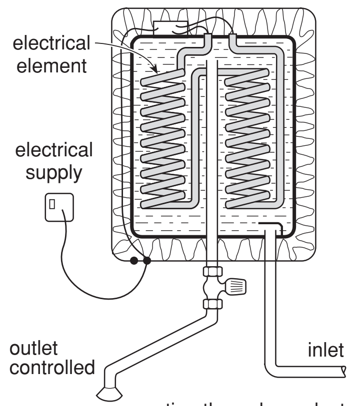
Storage type single points

These heaters are located either above or below a sink or similar appliance and have a capacity not exceeding 15 litres. The stored water is heated by an electric element to, for example, 60°C, and on expanding the water is allowed to push up and discharge from the discharge spout. It is important to make the client aware of this dripping spout. When cold water enters the base of the unit it forces the hot stored water out. Obviously the discharge of hot water is limited and will soon start to cool, but it will be sufficient for small quantities of draw-off. When installing these heaters below an appliance, a special design of terminal fitting (tap) needs to be used – one which allows water to flow through the heater but at the same time allows the water to expand (see figure).

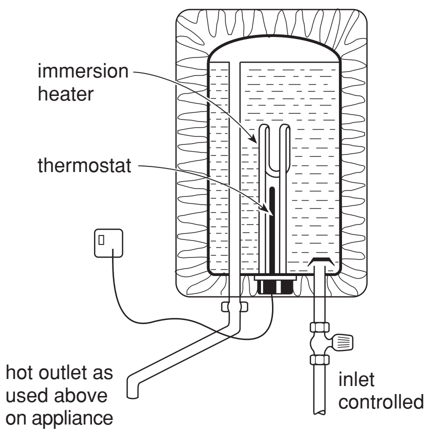
Some designs of single points incorporate a small expansion vessel which enables an outlet control valve to be used, eliminating dripping outlet spouts.

Single point gas water heater

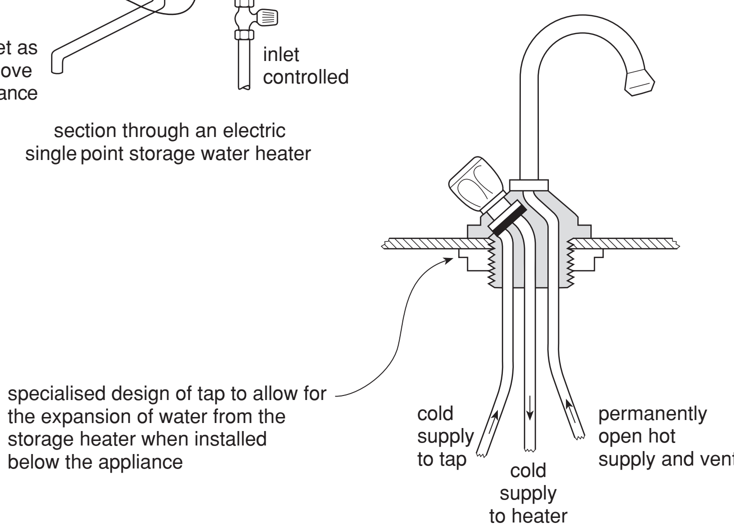
View inside a small electric single point heater



section through an electric instantaneous water heater



section through an electric single point storage water heater



Localised hot water heaters

Solar Hot Water System

Relevant British Standard
BS 5918

This is a dhw system which utilises energy from the sun. It collects the radiant heat waves in a solar collector, usually located on the roof. A simple solar collector consists of a thin vessel painted matt black with piping attached flowing to and from a hot storage vessel. It is covered with double- or triple-glazing and backed by thermal insulation material. The collector is sited at a convenient position to catch the solar heat, usually at an angle of 40° and facing south.

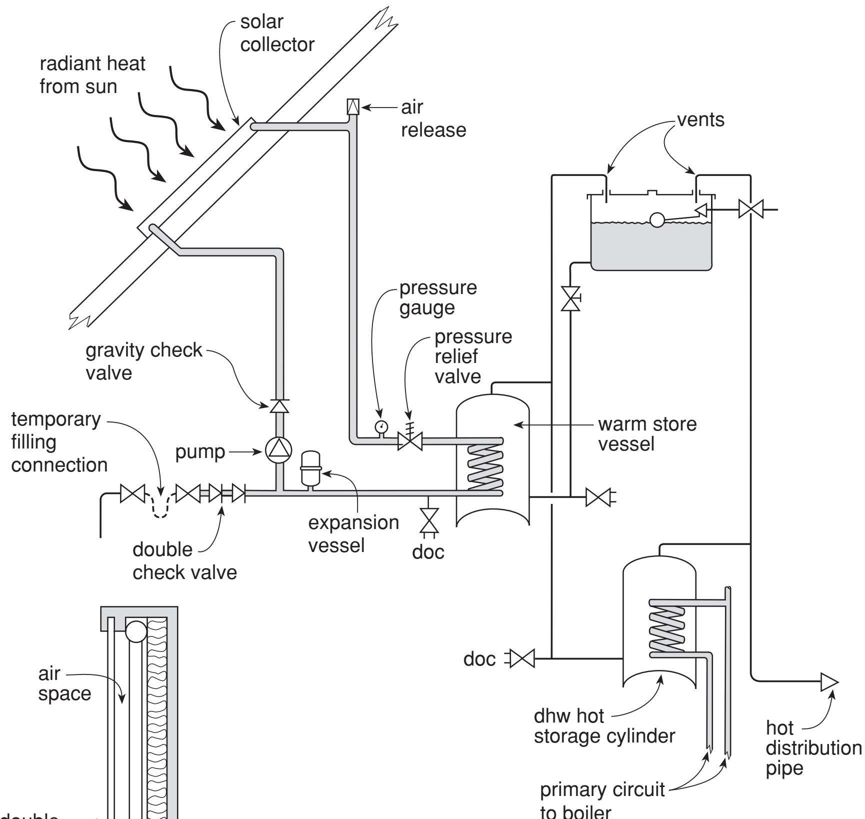
Designs of solar heating systems can vary, and because of the unreliable weather in the UK, would not be used in any dwelling as the only form of heating for water. Generally, cold water is supplied to a warm store vessel which is heated by solar energy; the water then passes onto the normal conventional hot storage cylinder and is supplied with additional heat (if required) by a boiler or electric immersion heater. Note that in the system shown opposite, the solar collector is fitted above the cold feed cistern. This causes no problems because the primary circuit from the solar collector forms part of a closed system. The water in the primary circuit is made to circulate by means of a pump which is switched on automatically should the temperature in the top of the collector be higher than that in the base of the hot storage vessel. However, it is possible to design a gravity system, providing the collector can be located sufficiently far below the warm store vessel to allow circulation to take place.

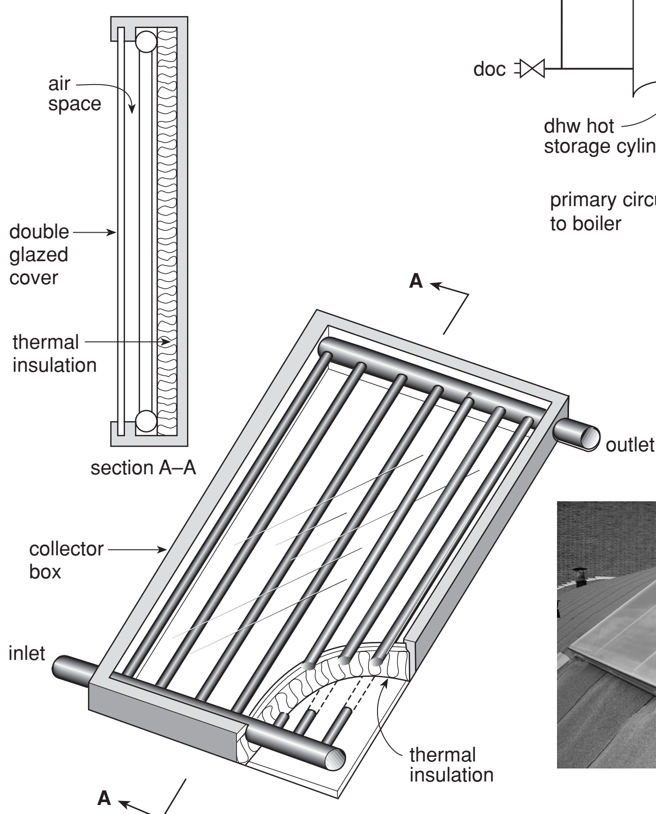
Thermal performance Based on a long-term average temperature in London, the system should supply an approximate percentage of that indicated in the following table. However, the amount of solar energy supplied to the dhw system will vary from area to area, and will depend upon the effectiveness of the solar collector and its location. It should be remembered that trees and buildings casting shade will significantly reduce system performance.

Approximate monthly percentage for solar heating system, in the London area, on a south facing 30° pitched roof

	%		%
January	2	July	13
February	5	August	13
March	6	September	12
April	10	October	8
May	12	November	4
June	13	December	2

Design considerations Due to temperature changes, the temperature of the heat transfer liquid could vary from about −15°C to as high as 200°C, when not circulating; where water is used for this (see figure) it will be necessary to prevent the temperature from rising above 100°C by incorporating a pressure relief valve as a minimum requirement, discharging its contents to a safe location. To prevent damage due to excessively cold conditions, an anti-freeze solution may be added; alternatively the system will need to be drained in winter. Usually planning permission will need to given by the local authority before a solar heating system can be installed.





Typical flat plate collector

Solar panel

Solar hot water system

Connections to Hot and Cold Pipework

Relevant British Standards
BS EN 806-2 and BS 6700

Connections to showers

The hot and cold supplies to a shower will need to be of equal pressure. Where the supply is directly from the service main, provision must be made to ensure no backflow occurs. This is usually achieved by ensuring that the shower head cannot discharge below the overspill level of the appliance or by incorporating a double check-valve assembly into the pipeline.

Connections via a storage cistern will need to be such that an adequate pressure is achieved; in general, a minimum distance of 1 metre from the underside of the cistern to the shower head should be maintained. The pressure can be increased by the use of a booster pump fitted into the pipeline in which a small self-contained unit, designed to give a greater head of water, is used. The only proviso is that at least 150 mm of initial head is available to allow the flow switch to operate and start the pump when the supply is opened.

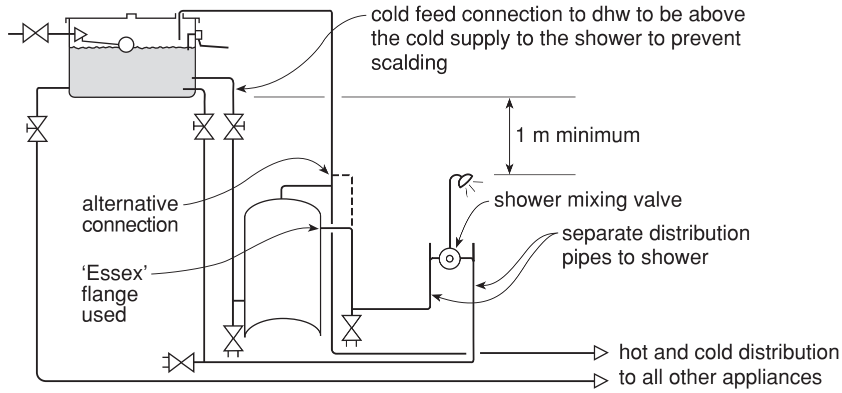
It is possible to use a flow-activating button where no head at all is available for some designs of pump. Booster pumps may be fitted before or after the shower-mixing valve, although in general they should be installed in such a location as to ensure that it is constantly flooded with water. Where a shower booster which draws more than 12 litres/min is considered, the water authority may need to be advised regarding its use.

To ensure that the shower is never starved of water, the cold supply to the shower mixing valve should be independent of other draw-off points and its connection to the storage cistern should be below that of the cold feed to the dhw cylinder.

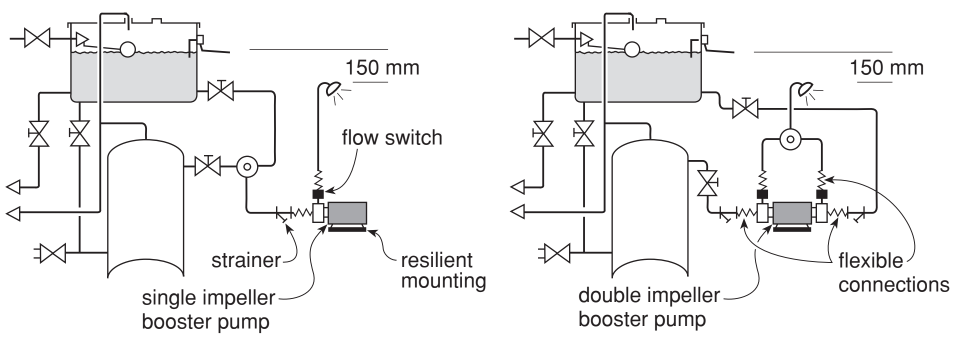
The temperature of the water to the shower is regulated by means of manual or thermostatic control. With the manually controlled valve, a dial on the control head is turned to open or close either the hot or cold porthole size, thus restricting the flow. Thermostatic mixing valves are fitted with a temperature-sensing device which is designed to expand due to heat and should maintain a constant outlet temperature, opening or closing the portholes automatically as required.

Connections to bidets

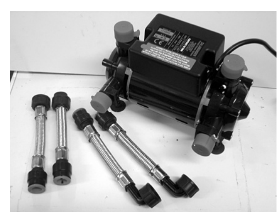
There are two types of bidet: those with pillar taps to give an over-the-rim type discharge, thus maintaining an air gap; and those with a submerged nozzle which discharges a spray of water upwards from the base of the appliance. Those with an ascending spray are not permitted to be connected directly to the supply main and must have their hot and cold supplies run via separate distribution pipes, independent of other draw-offs. This can be achieved as shown in the figure. Note that a check valve and an additional separate vent pipe from the hot distribution pipe to the appliance are required.



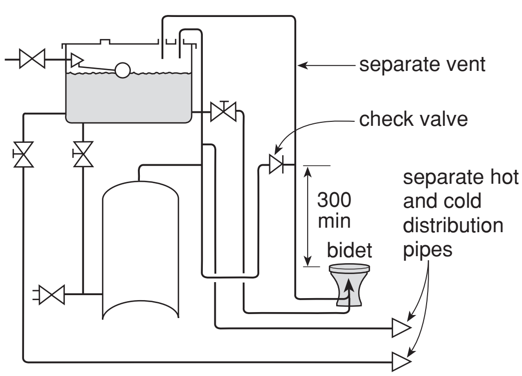
Storage fed shower



Installation of shower booster pumps

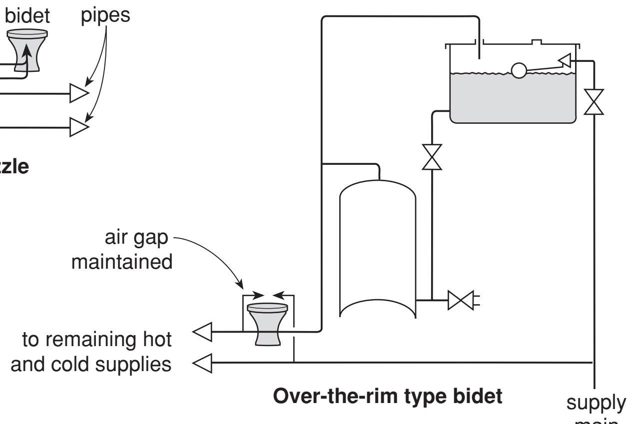


Shower booster pump



Bidet with submersible nozzle

Connections to bidets



Over-the-rim type bidet

Connections to hot and cold pipework

Installation of Pipework 1

Relevant British Standards
BS EN 806-2 and BS 6700

Pipe supports

There are many designs of pipe support bracket and the one chosen will depend upon the material nature of the pipe, the cost allowed for the job, and upon circumstances; for example, it would be pointless to use plastic pipe clips in schools or hospitals, etc., where they could very easily be damaged. Whatever pipe support is chosen, the fixing must be secure to prevent damage and the possible development of air locks. As a guide, the general recommended pipe support spacings are given in the following table, but one must remember that one clip too many is better than one clip too few and, in many cases, plumbers have to use their own judgement.

Maximum spacings for internal pipework (m)

Pipe size		Copper pipe		Steel pipe		Plastic pipe	
(mm)	(in)	horizontal	vertical	horizontal	vertical	horizontal	vertical
15	$\frac{1}{2}$	1.2	1.8	1.8	2.4	0.6	1.2
22	$\frac{3}{4}$	1.8	2.4	2.4	3.0	0.7	1.4
28	1	1.8	2.4	2.4	3.0	0.8	1.5
35	$1\frac{1}{4}$	2.4	3.0	2.7	3.0	0.8	1.7
42	$1\frac{1}{2}$	2.4	3.0	3.0	3.6	0.9	1.8
54	2	2.7	3.0	3.0	3.6	1.0	2.1

Design considerations

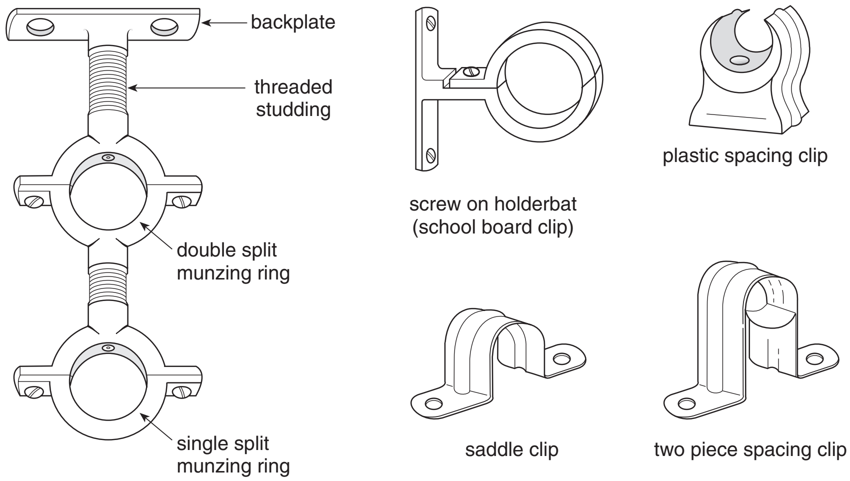
If the pipe is to run through structural timbers such as floor joists, it is essential that the structural members are not weakened. Notches and holes should be as small as practicable, but should also allow for pipe expansion and contraction. The size and position of a notch or hole need to be considered and should not exceed the dimensions in the figure.

Example: For a joist 200 mm deep and 3m long (measured from centre line of the bearing) any notch must have a maximum depth of H ÷ 8

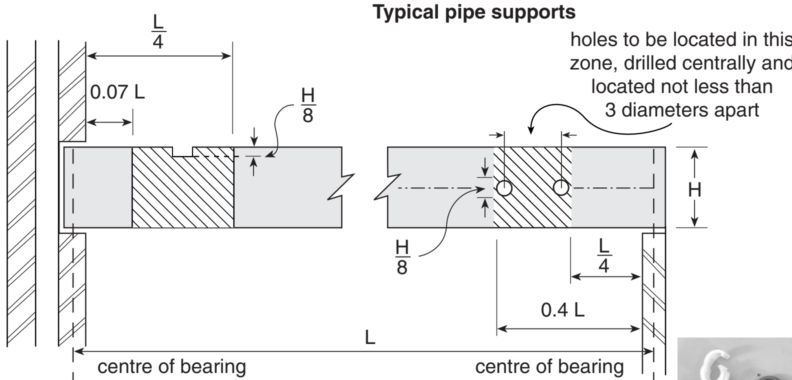
$$\text{Therefore notch depth } 200 \div 8 = 25 \text{ mm}$$

and be at least 0.07 L from its bearing; therefore $0.07 \times 3000 = 210$ mm
and no greater than L ÷ 4 from its bearing; therefore $3000 \div 4 = 750$ mm.

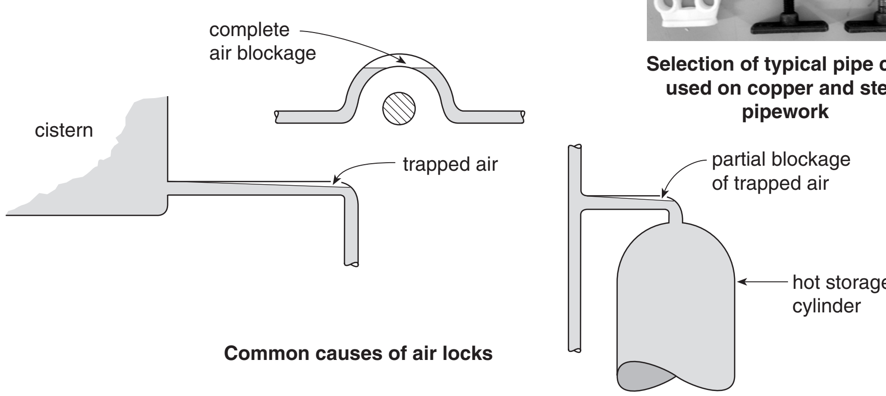
In vented systems the pressure is usually quite poor in comparison with mains supply pipework. Therefore, it is essential to run the pipework with no dips or high spots, which may allow a trap of air to form, causing a blockage (air lock). To this end, pipes should be run horizontal, or to an appropriate fall, allowing the air to escape from the system.



Typical pipe supports



Selection of typical pipe clips used on copper and steel pipework



Common causes of air locks

Installation of pipework 1

Installation of Pipework 2

Relevant British Standards
BS EN 806-2 BS 5422 and BS 6700

Thermal insulation

When installing any pipework, steps need to be taken to prevent the pipe contents from *freezing* in the case of cold water supplies and *losing heat* in hot water systems. Therefore, some form of insulation may be required. Insulation materials entrap small air pockets which are a poor conductor of heat. Should a pipe freeze, damage can occur to the pipework; therefore, insulation is imperative in exposed locations. Roof spaces and garages must be regarded as exposed. The insulation requirements depend on the thermal conductivity of the insulation material. The following table gives a guide to the minimum insulation for frost protection in housing.

Minimum thickness of insulation material

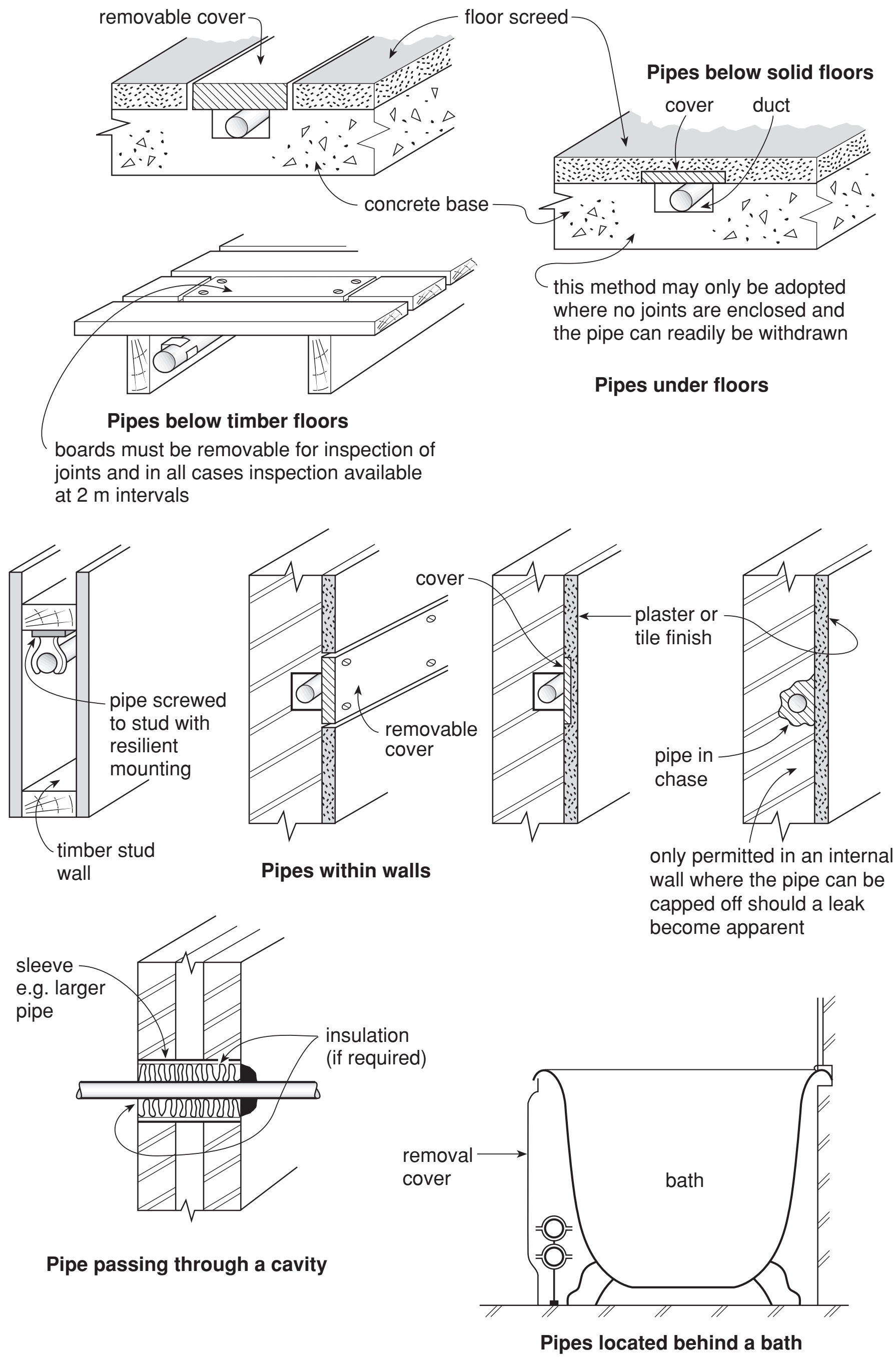
	Indoor installations (e.g. roof space)		Outdoor installations (including below ground)	
Outside pipe diameter (mm)	Flexible foam and expanded plastic (mm)	Loose-fill (mm)	Flexible foam and expanded plastic (mm)	Loose-fill (mm)
0–15	22	89	27	100
16–22	22	75	27	100
23–42	22	75	27	89
43–54	16	63	19	75
Flat surfaces	13	38	16	50

It should be noted that smaller pipes require a greater thickness of material because they are more prone to freezing up.

Accessibility of pipework

It is a water regulation that all water pipes and fittings be readily accessible for inspection and repair. Often the designer/installer has no wish to see exposed pipework; therefore, a duct or chase is made in the wall, etc., and enclosed by a cover to allow movement and ease of removal. This cover may be covered at the choice of the client with plaster or a tile finish (see figure for examples). Note that thermal insulation material may also be required in exposed or unheated dwellings, although not shown in the examples. It is only possible to encase the pipe in the floor screed where it forms part of a heating element of a closed circuit of under-floor radiant heating.

When passing pipes through floors or walls, the pipe should be sleeved to allow movement, and the space between the pipe and sleeve 'fire stopped' to prevent the passage of smoke and flame.



Installation of pipework 2

Sizing of Hot and Cold Pipework

Relevant British Standards
BS EN 806-2 and BS 6700

For everyday plumbing in a domestic dwelling, the installer uses a rule of thumb (tried and tested) method which consists of 15–22 mm pipe on the supply main and a 22–28 mm pipe for the hot and cold distribution pipework. In each case the larger size is chosen if there are many draw-off points, the pipe slowly reducing in size as necessary to each appliance. For bigger systems requiring many outlets over a large area or several floors, the main distribution pipe run will need to be sized correctly to ensure sufficient pressure and flow at the draw-off points, without excessive noise problems.

Shown opposite is a completed table, which acts as a key to the figure below it. An explanation of the stages carried out to choose the pipe sizes is as follows.

Column 1 This is the pipework which is being sized; note that the system is broken into various sections.

Column 2 The flow required is found by making an assessment of the probable maximum demand of water, in litres per second, at any given time, because it is very unlikely that all the sanitary appliances will be used at once. To perform this assessment, a method has been devised based upon the theory of probability, in which a loading unit rating is given to each type of sanitary appliance.

Sanitary appliance	Loading unit
WC cistern	2
Bath	10
Wash basin	$1\frac{1}{2}$
Sink and washing machine	3
Shower	3
Bidet	1

By multiplying the number of each type of appliance by its loading unit and adding together the results, the total loading units for the system will be found.

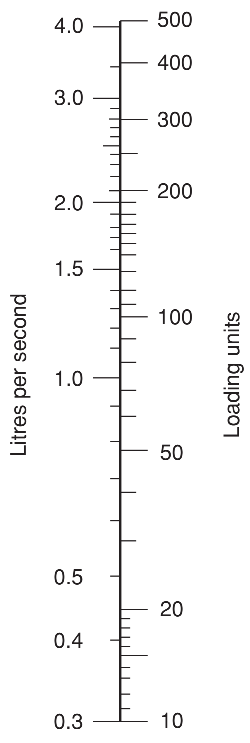
To convert loading units to flow rate (litres per second), the conversion table opposite is used. Thus, in our example, where each floor has one bath, two basins and two WC cisterns, the number of loading units is:

$$\begin{array}{ll}
\text{Bath:} & 1 \times 10 = 10 \\
\text{Wash basin:} & 2 \times 1\tfrac{1}{2} = \ \ 3 \\
\text{WC cistern:} & 2 \times \ 2 \ = \underline{\ \ 4} \\
\text{Total:} & \qquad\quad 17 \text{ loading units}
\end{array}$$

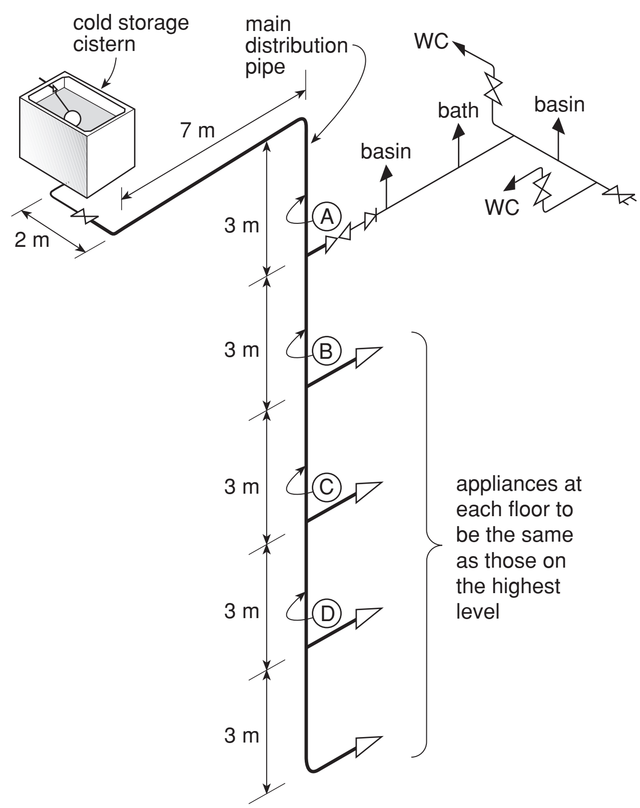
From the conversion table opposite, 17 loading units gives a flow rate of 0.4 litres/s. Note that for pipe section A all five floors are being served; therefore the total loading units for this section will be: 17 × 5 = 85, which converts to a flow rate of 1.1 litres/s.

Cold distribution pipe serving five flats

1	2	3	4	5	6	7	8	9	
Section	Flow rate (l/s)	Suggested pipe size (mm)	Velocity (m/s)	Loss of head (m)	Effective pipe length (m)	Frictional head (m)	Progressive head (m)	Actual head (m)	Notes
A	1.1	28	1.8	0.2 ×	16.5 =	3.3	3.3	3	Undersized
A	1.1	35	1.25	0.07 ×	18.2 =	1.27	1.27	3	✓
B	0.92	28	1.5	0.15 ×	4.5 =	0.68	1.95	6	✓
C	0.8	22	2.2	0.43 ×	4.0 =	1.72	3.67	9	Possible noise
C	0.8	28	1.3	0.12 ×	4.5 =	0.54	2.49	9	✓
D	0.6	22	1.6	0.27 ×	4.0 =	1.08	3.57	12	✓



Conversion table
(loading units to litres/sec)



Pipe sizing of hot and cold pipework

Column 3 An assumption is made at this stage that a particular pipe size is correct, and the table will confirm (or reject) its possible use.

Columns 4 and 5 The velocity and loss of head can simply be read from the graph opposite. To use, take a horizontal line from the flow in litres per second to intersect the pipe diameter; from this point the readings can be taken.

Column 6 The effective length of pipe run is found by adding the actual net length of pipe to the length of pipe due to frictional loss.

Equivalent pipe lengths, due to frictional loss through copper fittings

Pipe o.d (mm)	Elbow (m)	Tee (m)	Stopcock (m)	Check-valve (m)
15	0.5	0.6	4.0	2.5
22	0.8	1.0	7.0	4.3
28	1.0	1.5	10.0	5.6
35	1.4	2.0	13.0	6.0
42	1.7	2.5	16.0	7.9
54	2.3	3.5	22.0	11.5

In the example given, the effective length for section A, with an assumed pipe diameter of 28 mm, is:

$$\begin{aligned} \text{Actual length} &= 12.0\,\text{m} \\ \text{Three elbows} &= 3.0\,\text{m} \\ \text{One tee} &= \underline{1.5\,\text{m}} \\ \text{Total} &= 16.5\,\text{m} \end{aligned}$$

Column 7 The frictional head is found by multiplying the loss of head by the effective pipe length (i.e. column 5× Column 6).

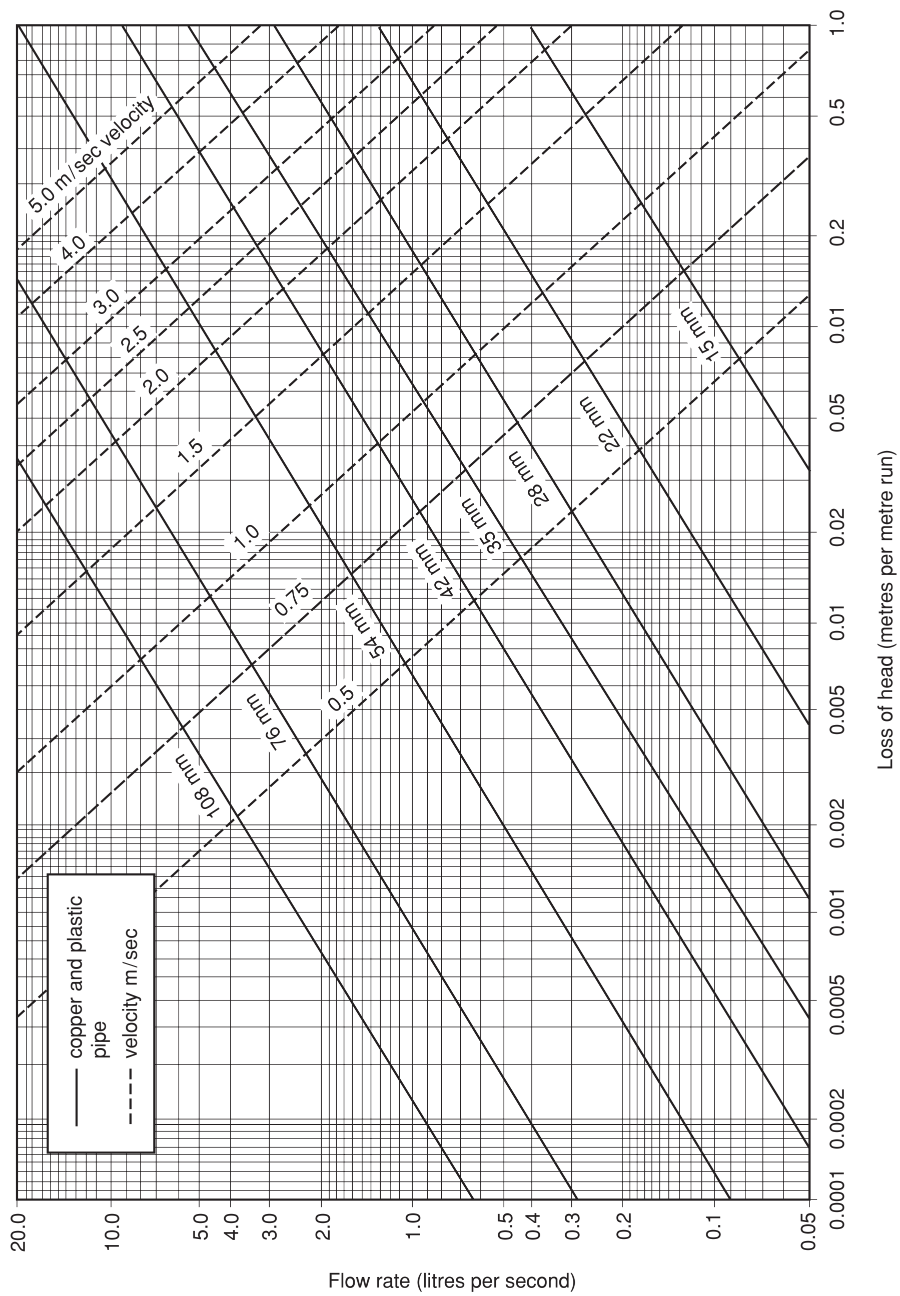
Column 8 The progressive head is the sum total of the frictional heads for each section above the section in question.

Example: The progressive head for section C will be sections A + B + C

$$\text{Therefore } 1.27 + 0.68 + 0.54 = 2.49\text{ m}$$

Column 9 The actual head is the total head available; it is standard practice to measure this vertically from the underside of the storage cistern to the end of the section of pipe in question.

In conclusion, one estimates a suggested pipe diameter and completes the table for the section to prove its suitability for use. The pipe size is correct provided that the progressive head does not exceed the actual head and the velocity does not exceed 2 m/s in cold water pipework and 1.5 m/s in dhw systems, thus limiting noise transmissions.



Pipe sizing of hot and cold pipework

(Reproduced with permission of The Institute of Plumbing and Heating Engineering)

Noise Transmission in Pipework

Relevant British Standards
BS EN 806-2 and BS 6700

Impulsive noise (water hammer)

A hammering noise which occurs in high pressure water pipes; the noise is caused by surges of pressure. There are two basic noise types:

(1) A noise which consists of a sudden loud bang and is often caused by a loose stopcock jumper or washer which quickly flips shut onto the seating. It may, on the other hand, be caused by pipes which have not been fixed correctly and flap about; in which case the noise is caused by sudden back surges of pressure, perhaps created by the rapid closing of a tap.
(2) Oscillation or ballvalve murmur which consists of a series of bangs or rumbles generated in the pipeline. The noise is created by a float-operated valve quickly opening or closing, this being caused by ripples or waves which form on the surface of the water in a storage cistern. To overcome this problem, a larger ballfloat is often used or a damping plate fitted to the float or ballvalve lever arm; alternatively, baffle vanes are fitted in the cistern to prevent waves forming.

One method often employed to cure water hammer is to shut down slightly the incoming stop-valve. This does not reduce the pressure but it reduces the flow rate of the water.

Flow noise A general noise caused by the water flowing through the pipework. If the water velocity is kept below 3 m/s in high-pressure pipework and below 2 m/s in low-pressure pipework, this flow noise will not be significant. Sudden changes of direction and minimal downstream pressures can cause cavitation, which is turbulence, causing air bubbles to form and collapse. Flow noise can result unnecessarily when one uses roller pipe cutters and fails to remove the internal burr.

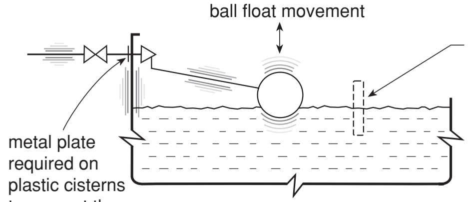
Pump noise When a booster pump has been provided, noises should not be generated by water pressure and flows, providing the pump is correctly sized. However, the noise of the motor running may give concern, in which case isolation of the pump from the building is the only answer. Noise transmission from pumps can be reduced by using rubber-type connections to the pipework and installing the pump on a resilient mounting.

In large buildings, excessive water noise problems may be overcome by the installation of a hydropneumatic accumulator. This consists of a rubber bag into which the water can enter; the air surrounding the bag is charged to just below the system working pressure. Should a shock wave occur in the pipework, the pressure surge is taken up by the cushion of air.

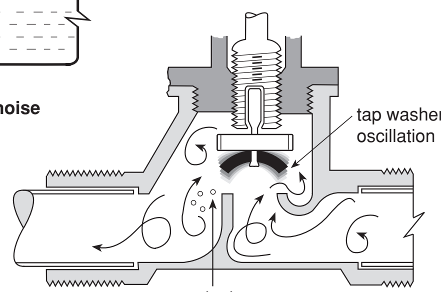
Splashing noise When water drops into cisterns the falling water can be somewhat noisy. To prevent this, a collapsible silencer tube can be used, consisting of a polythene bag. It is sometimes possible to discharge the water onto an inclined plate, which breaks the waterfall and inhibits the resulting splashing sound.

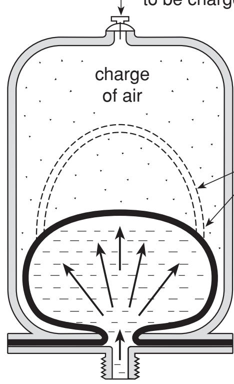
Movement noise When pipes, especially hot pipes, expand and contract they need to move and as a result must not be restricted (see pages 120–123 which identify good pipework installation practices).

Entrapped air bubbles and boiler noise This is the result of poorly installed pipework allowing air to be entrapped in dhw systems. Sometimes, owing to scale build-up in the flow from a boiler, a boiling noise (kettling) is generated, which is caused by steam forming and condensing. A similar noise is also caused where a flame impinges onto the heat exchanger, causing local hot spots.

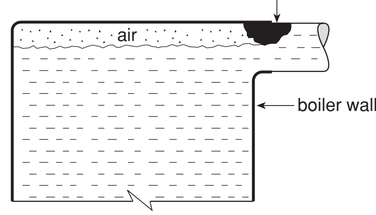


oscillation type noise



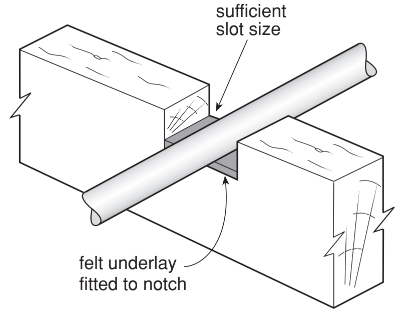


hydropneumatic accumulator



trapped air within boiler

Flexible connections to reduce noise from booster pump



Noise transmission in pipework

Commissioning of Hot and Cold Supplies

Relevant British Standards
BS EN 806-2 and BS 6700

When a system of hot or cold water supply has been installed, it should be inspected and tested appropriately. The following checklist should be followed:

(1) **Visual inspection** All pipework should be inspected to ensure it is fully supported and free from jointing compounds, flux, etc. The feed or storage cistern should be cleaned and made free of swarf. All valves should be closed to allow filling up in stages.

(2) **Testing for leaks** The system should be slowly filled in stages. Air should be expelled by opening the highest draw-off point on the section being tested. The testing is carried out in stages so that any leaks can be identified easily. Before opening the isolation valve to a cistern, the float-operated valve seating should be temporarily removed to allow any grit, etc., in the pipe to flow into the cistern, thus preventing the blockage of the small hole in the seating itself. When the valve is reassembled, the water level should be adjusted as necessary.

Sometimes it is desirable to test the installation using a hydraulic test pump, giving a test pressure of one and a half to two times the system working pressure. This is achieved as shown in the figure, the test pressure being maintained for at least 1 hour. Pipework which is to be encased must be tested in this fashion prior to the connection of the water supply to prevent the need for costly removal of the encasement cover.

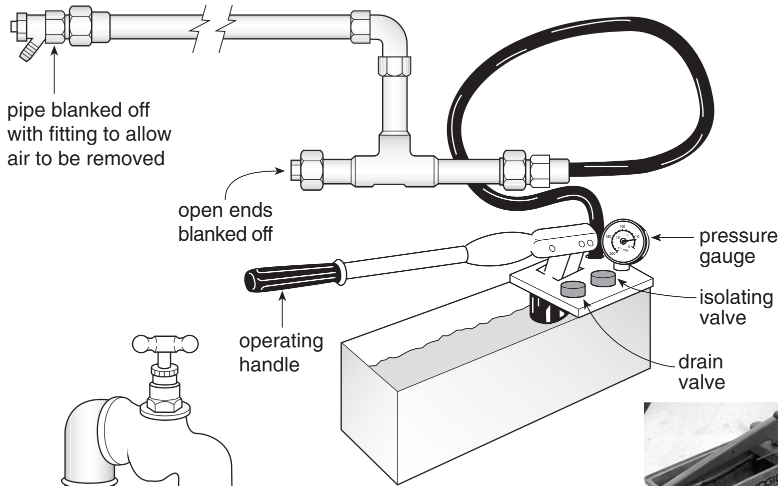
(3) **System flushing and disinfection** All systems, large or small, will require the flushing through of the pipeline to remove flux residuals, wire wool, etc., from inside the pipe – usually achieved by opening the tap or draining off for a period of time. Domestic hot water systems should be flushed both cold and hot; this will give a better removal of the deposits from within the system. The BS requires that all systems other than those of private domestic dwellings be disinfected before being put into use. This is carried out after any initial flushing and is achieved by dosing the system with a measured quantity of sodium hypochlorite solution. The procedure outlined over the page should be observed.

(4) **Performance tests** Every terminal fitting, e.g. draw-off point, float-operated valve, should be checked for suitable flow rate (volume of water) and pressure, and that it is operating to give suitable performance. For example, it would be pointless having an appliance with 3 bar pressure if the water only passed through a pinhole; it would take for ever to fill.

The performance test must be carried out under probable flow demands, i.e. several appliances should be opened at once. Generally the pressure and flow performance tests are carried out by visual inspection, but it is possible to use a pressure gauge and flow measuring device to ensure that the performance meets the required specification. A check should also be made at this stage for noise transmissions in the pipeline caused by rapid closure of valves.

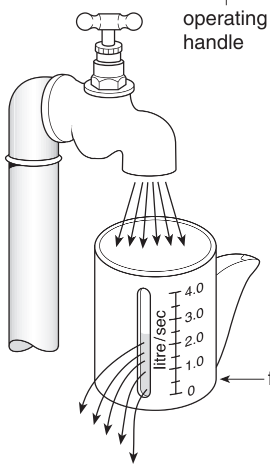
All dhw thermostats will need to be inspected for correct operation and adjusted to maintain the required water temperature, not exceeding 60°C.

(5) **Final system checks** After any problems have been resolved, cistern lids should be secured, insulation material applied, and labels fixed to valves for identification purposes, as necessary. The job should be left clean and tidy.

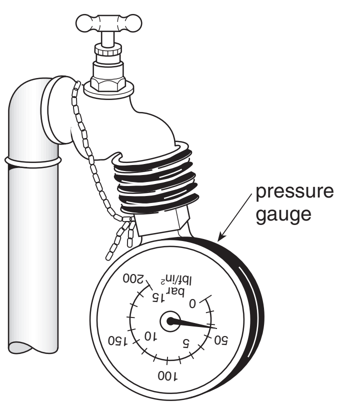


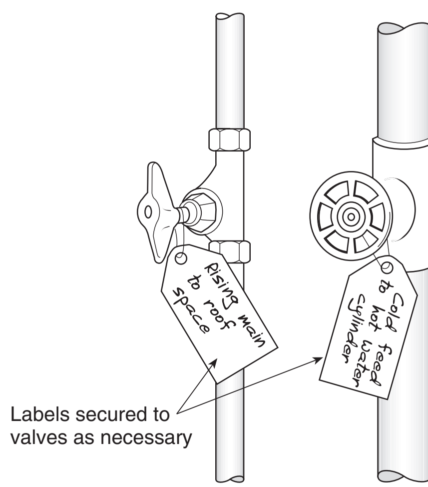
Hydraulic pressure testing

Pressure and flow test equipment



Test for water pressure and flow





Commissioning of hot and cold supplies

Disinfection of Hot and Cold Water Systems

Relevant British Standards
BS EN 806-2 and BS6700

In relation to industrial and commercial hot and cold water systems used for potable water supplies it is a requirement that the system is maintained in a condition fit for its purpose. As a result these water systems need to be disinfected in the following circumstances:

- Where it is a new installation or has had a major extension
- Where it is suspected that contamination may have occurred
- Where a system has not been in regular use
- Where water is stored in a way that could create the risk of legionnaire's disease.

Disinfection is carried out by thoroughly flushing and filling the system with a measured quantity of chlorinated water at 50 ppm. Chlorination is achieved using a sodium hypochlorite solution (similar to household bleach). The solution may be of various strengths, usually between 5 and 10%, therefore the quantity added to the system needs to be carefully considered. Where unknown it is best to assume it to be 10%. Thus if we wish to create a concentration of 50 ppm we would require $50 \div 1\,000\,000 \times 100 \div 10 = 0.0005$ parts of sodium hypochlorite to one part water, which equates to **1 litre to every 2 000 litres** of water in the system.

Assessment of system volume This can be calculated by using the formulae identified on page 34. To assist, the following table identifying water volumes in copper tubes may be of use.

Water volume (litres per meter run) for copper tube to BS EN 1057

Tube size	Litres/m	Tube size	Litres/m	Tube size	Litres/m
15 mm	0.145	35 mm	0.835	66.7 mm	3.247
22 mm	0.320	42 mm	1.232	76 mm	4.197
28 mm	0.539	54 mm	2.091	108 mm	8.659

Safety Prior to undertaking any process of disinfection you must give notice to all parties, including the water authority who may have concern for the water discharge. Locate and mark all outlets with an appropriate warning notice advising of the operation taking place. In order to avoid toxic fumes being generated no other chemicals, such as toilet cleaner, should be added to the water discharge until the process has been completed. COSHH data sheets should be reviewed and appropriate personal protective equipment used (i.e. goggles and gloves) when mixing the solution. Where necessary it is possible to remove the chlorine from the water by mixing with a neutraliser solution, such as sodium thiosulphate, added at a rate of:

$$\text{System volume } (m^3) \times \text{ppm(mg/L) chlorine} \times 2 = \text{No. of grams required}$$

Disinfection procedure for gravity fed systems

1. Undertake the safety procedures described and position warning notices
2. Thoroughly flush new systems to remove flux residuals and swarf
3. Calculate the capacity of the cistern and add to this water 1 litre of sodium hypochlorite for every 2000 litres (to check dose is correct see below).
4. Working from the cistern, open each draw-off point until the disinfection solution is detected, usually by smell. Then close this fitting and move to the next outlet, slowly progressing around the system, drawing the solution to all points. As the chlorinated water is drawn off from the cistern it will be necessary to maintain the 50 ppm concentration.
5. Once the entire system is full of chlorinated water at the correct dose the system is left for 1 hour.
6. After the hour has elapsed the chlorine level should be checked in the cistern and at selected outlets. Where this level is less than 30 ppm you need to re-dose and leave for a further hour.
7. Upon successful completion the chlorine can be neutralised before draining.
8. Finally the system is thoroughly flushed with clean water until the residual chlorine level at the outlets is no higher than that present in the supply mains (0.2 ppm).

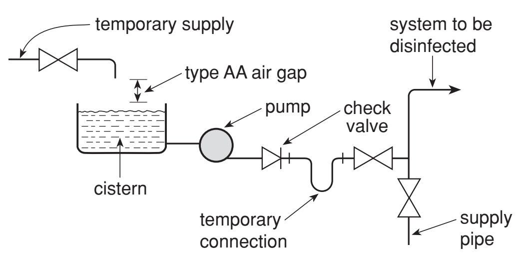
Disinfection procedure for mains fed systems

Where no storage cistern is available to introduce the sodium hypochlorite solution it will be necessary to introduce a temporary branch connection. This allows for a pump, checkvalve and cistern, as shown below, to be introduced, thereby allowing the solution to be added. During dosing the supply would need to be isolated. It may be possible to add the solution to the highest point in the system, eliminating the need for a pump.

Checking the chlorine concentration

This is achieved by using a simple colourimetric test. The procedure involves filling a small clear plastic tube with a sample of water to be checked. To this is added a special tablet. The tube is shaken to dissolve the tablet and the colour of the water is inspected, which, when compared with the following table, gives an indication of the chlorine level.

Water colour	Chlorine level (ppm)
Clear	0
Light pink	0.2–1
Dark pink	1–5
Red	5–10
Purple	10–20
Blue	20–30
Grey/green	30–50
Yellow/brown	Over 50
Colour develops then clears	Excessive



Temporary connection for dosing mains supplies

Maintenance and Servicing Schedule

Relevant British Standards
BS EN 806-2 and BS 6700

No system can be guaranteed for ever, but its life expectancy can be greatly improved by identifying faults before they have a chance to cause inconvenience. Planned preventive maintenance, regularly carried out, will not only help to ensure that the system performs as it was intended, but may also prevent costly damage to equipment and buildings. A maintenance schedule is generally drawn up, and should be observed, giving guidance on what to look for when fulfilling the terms of a servicing contract.

Shown is a typical schedule as used when inspecting a system of hot and cold water supplies.

Maintenance schedule

Date of Inspection: __________
Inspected by: __________
Remarks: __________

Inspection carried out at:

Component	Remarks	Inspected	Notes
Meters	* Read meter and check water consumption for early signs of wastage * Confirm in correct working order		
Meter and stop valve chamber	* Ensure ease of opening to access covers * Clean out as necessary		
Earth bonding	* Check for alterations and suitable earth bonding maintained		
Water analysis	* '6 month' chemical and bacteriological analysis of drinking water systems where bulk storage exceeds 1000 litres		
Inspection covers and ducting	* Ensure ease of opening to covers and clean out service ducts as necessary * Check for signs of leakage from pipework and surrounding ground or surface water * Check for the accumulation of gas		
In-line control valves	* Operate and confirm easy and effective operation * Labels clearly identify their purpose and are securely attached * Emergency valve keys readily available		
Terminal valves	* Check for suitable operation and effective closing * Remove scale build-up and clean sprayheads of shower mixers, etc. * Check timing delay of self-closing taps * Adjust water levels to float operated valves * Check for suitable pressure and flow at outlets		

Component	Remarks	Inspected	Notes
Pipework	* Check supports and inspect for loose fittings * Check provision is maintained for expansion and contraction * Check for soundness of pipework * Inspect for signs of corrosion * Inspect insulation material for soundness * Inspect fire stopping to ensure that it is maintained		
Storage cisterns	* Confirm the cleanliness of vessels * Look for signs of leakage * Check for stagnant water (e.g. dust on surface of water) * Check condition of cistern supports * Confirm operation of overflow * Ensure lid and insulation are sound		
Pumps	* Check operation of any pump(s) fitted and ensure noise levels are mimimal		
Pressure and temperature relief valves	* Open test lever to confirm valve not stuck down * Check discharge pipe not blocked		
Pressure-reducing valves	* Check pressures downstream of valve		
Pressure vessels	* Inspect for corrosion and leakage * Drain vessels of water and measure gas pressure; adjust if necessary		
Filters	* Remove gauze/mesh trap and clean out		
Electrical components	* Check operation of all controls to include thermostatic devices * Check suitability of wiring to IEE standards		

Any system that has not been fully maintained may fail to meet the requirements of an insurance policy should a system failure result in damage to the property.

Operative taking water flow, pressure and temperature measurements