HOT AND COLD WATER SUPPLY SYSTEM

INTRODUCTION

Hot and Cold water systems in buildings are used for washing, cooking, cleaning and other specialized functions.

Cold water for buildings is also known as potable water.

Non-potable is supplied in some countries; this is not for drinking or cooking.

Water services should be designed and installed in accordance with the recommendations of BS 6700, the Water Regulations, relevant statutory regulations, byelaws, other relevant British Standards and manufacturers' recommendations. The Water Regulations are interpreted in the Water Regulations Advisory Scheme Water Regulations Guide which provides assistance in applying the regulations.

The Water Byelaws have been replaced since the establishment of individual water companies in the UK.

The Water Supply (Water Fittings) Regulations 1999 came into force in July 2000.

The Regulations apply only to England and Wales.
Scotland has introduced new Byelaws that impose similar requirements in Scotland.
Northern Ireland will have similar Regulations.

For information on health care premises, reference should be made to Health Technical Memorandum HTM 2027.

The responsibility for compliance with the Water Regulations rests initially with the owners or occupiers of the property.

WATER SUPPLY SOURCES

Most buildings can receive their **water supply** from the Water Authority's main (the D.O.E. Water Service in N.I.), but in rural areas it is sometimes necessary to obtain water from private sources such as:

- wells
- springs
- rivers
- Lakes.

The public water supply in **Northern Ireland** comes from Lough Neagh and various **reservoirs** throughout the country. Lough Neagh is a large inland fresh water lake into and out of which flows several rivers.

In some parts of the U.K. the water is supplied from **boreholes** but in one or two instances these have become polluted.

For human consumption, the best quality of water usually comes straight from the **ground**, rather than from a stream or pond which is exposed to probable air pollution.

In the case of Lough Neagh, the runoff from farm land brings **phosphates** from fertilizers into the Lough. This means that part of the water treatment process has to reduce to level of phosphate to an acceptable limit.

A dug **well** is normally of big enough diameter to admit a man and his spade and 3 to 6 meters deep is usual for this Northern Ireland. In some countries a **well** is much deeper to access strata of water bearing rock. It may be more economical to 'sink' a borehole in such circumstances.

A **borehole** is of small diameter and is made by a drilling rig - just big enough to admit the mechanical pump and delivery pipe. A typical borehole uses a **multi-stage centrifugal pump** delivering sufficient water from a depth of 30 meters to 60 meters. Most modern wells are **lined** with pre-cast concrete liners and boreholes with steel tubing.

In Northern Ireland rainfall is abundant and the geology of the sub-surface does not allow the widespread use of **artesian boreholes**. **Surface water**, whether in natural or man-made reservoirs, is therefore our main source of potable water supply.

In drier regions of the world the engineer has to study the most economic method of obtaining a suitable source of water for domestic and industrial use.

MAINS WATER TO BUILDINGS

Water mains can be divided into three categories:

(1) Trunk mains: these carry water from a source of supply (reservoir, pumping station etc.) to a district without supplying consumers en route.

(2) Secondary mains: the distribution mains, fed from a trunk main and supplying the consumers' connections in the district.

(3) Service pipes: the branch supplies from the secondary mains that serve individual premises.

It is important that a drinking water supply must not be liable to contamination.
There must be no inter-connection or cross-connection of the supply with any other water supply.

Reflux valves or stop valves are not considered adequate to prevent cross-contamination. The design of water services must be arranged to prevent the possibility of backflow or back siphonage into the water system from any outlet.

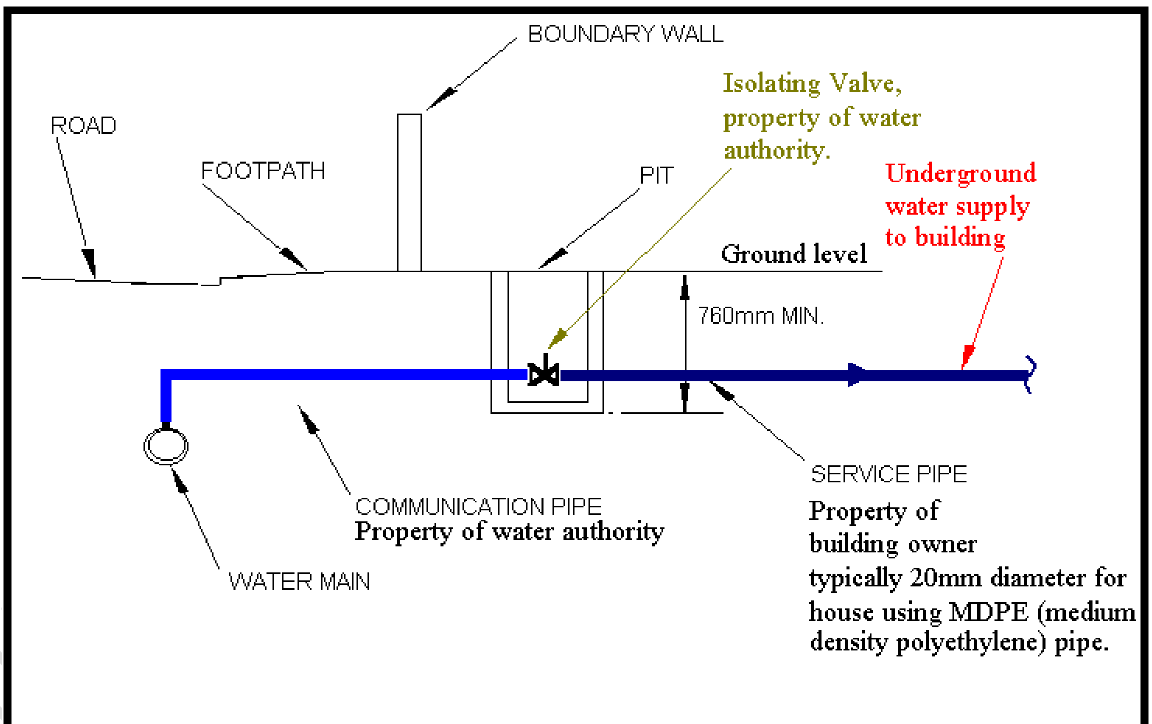
Mains connections

Connections to a trunk or secondary main are normally only carried out by the water supply company.
It is not normal practice to allow a service pipe to be connected to a trunk main. Connections to secondary mains may be made under pressure to connect pipes of 50 mm diameter and below, whereas for larger pipes a shutdown of the main is required.

Service pipes are fitted by the water supply company from the main up to the boundary (cartilage) of the premises to be supplied. At this point a stop valve is provided to enable the premises' water system to be isolated from the mains

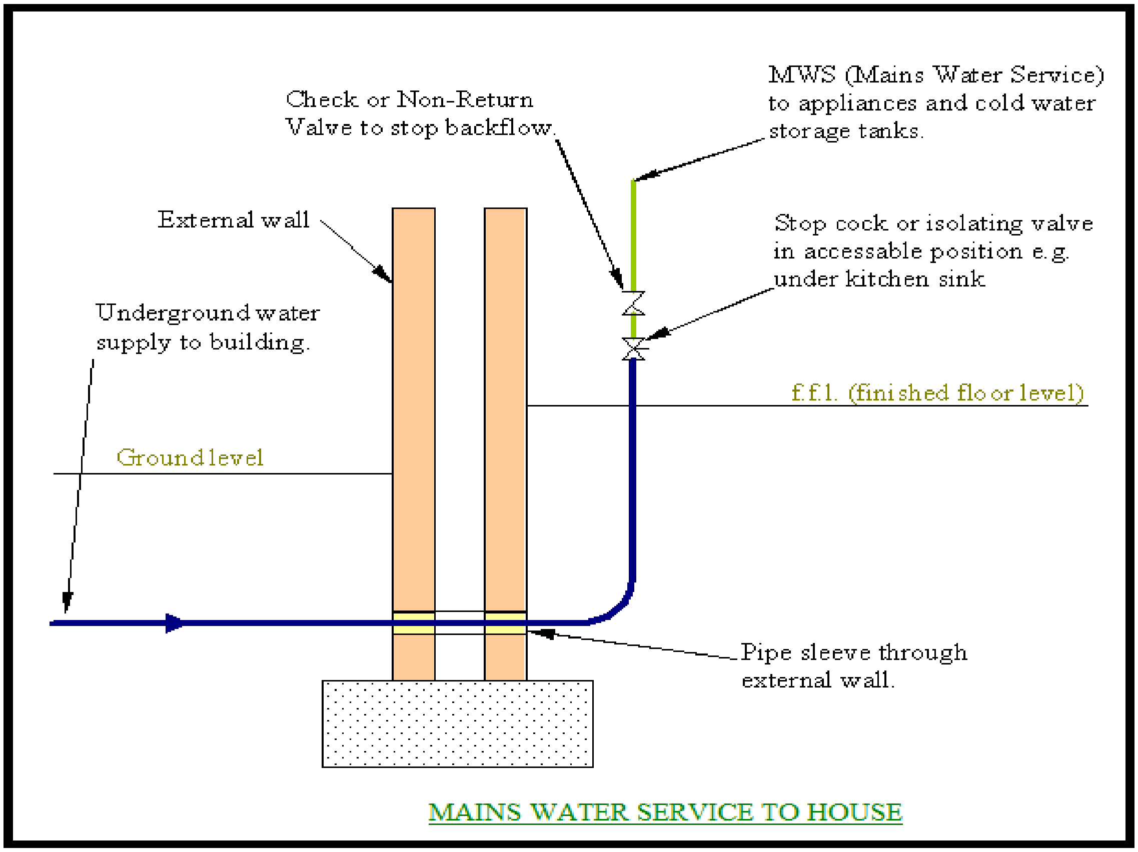
The drawing below shows a typical mains water connection to a domestic or industrial user.

It is often normal to have a meter installed so that water suppliers will be able to charge all customers on how much water is used.



CONNECTION TO MAINS WATER SYSTEM

The service pipe to the building should be kept at about 760mm minimum depth to avoid frost damage and damage from heavy vehicles.
The valve pit can be a purpose made plastic chamber with key operated lid.
This is sometimes situated in the footpath for ease of access if emergency isolation is required.



The above diagram shows the incoming mains water service to a building.
The pipe is sleeved so that movement of the pipe or settlement of the building can take place.

WATER QUALITY

It is important to have good quality of water for drinking and washing purposes.
This is achieved near the source by keeping reservoirs **clean** and in treatment plants throughout the distribution network.

In Northern Ireland private water supplies can have a **Hardness** problem or be **Acidic** if derived from peaty uplands.

Normal hard water is not a risk to health but can cause **scale** build-up in boilers and hot water systems, also hard water does not lather soap well.

SIMPLE CHEMISTRY OF WATER

Water is a chemical compound. It is a liquid which boils at 100°C and freezes at 0°C, and consists of water molecules.
Each molecule contains two hydrogen atoms joined to one oxygen atom.
It has the chemical formula H_20.
It is an excellent solvent and as a result normal drinking water contains dissolved substances such as iron (Fe), manganese (Mn), calcium (Ca), magnesium (Mg), sulphate (S04) and fluoride (F).
It will also contain dissolved gases including oxygen (0_2), nitrogen (N) and carbon dioxide ($C0_2$).
Many of the above minerals are essential for the health and proper growth of our bodies, but their content must be carefully controlled as must the possible content of harmful bacteria.
The presence of these minerals usually imparts a much more pleasant taste to water than would be the case with the "pure" compound.

The ability of rain to dissolve gases present in the atmosphere produces the formation of weak acids, e.g. -

$H_20 + C0_2$ H_2C0_3, carbonic acid
$H_20 + S0_2$ H_2S0_3, sulphurous acid
$H_20 + C0_3$ H_2C0_4, sulphuric acid

On penetrating layers of soil the water dissolves carbonates, chlorides, and sulphates of calcium and magnesium. It may also dissolve ammonia, silica and iron oxides. The amounts of each of these materials dissolved depends on the thickness and type of layers through which the water passes and on the solubility of the material. The presence of acids in the rain water increases its ability to dissolve many of the materials. In addition to chemicals, water may also contain micro-organisms e.g., bacteria, parasites, viruses and algae.

The pH of natural water varies from approximately 6.0 to 8.0 and depends on the type of rock through which the water passes. In some areas it may be as low as 4.0, e.g., due to acid rain. The pH scale which ranges from 0 to 14 measures acidity and alkalinity. The lower the value the more acidic the water.

pH less than 7	-	solution is acidic
pH greater than 7	-	solution is alkaline

HARD AND SOFT WATER

Soft water contains little or no dissolved solids.
It is often brownish or yellowish in colour.
Hard water, on the other hand, will have a high calcium or magnesium salt content.
Soft rainwater that percolates through certain types of rock strata e.g., chalk or limestone, will become "hardened" in this way. Hard waters do not form lather readily which has shaken with soap solution, whereas soft water lathers easily.
The table below sub-divides hard and soft waters into several classes depending on the hardness.

CLASS	HARDNESS ppm
Soft	0 - 50
Moderately Soft	50 - 100
Slightly Hard	100 - 150
Moderately Hard	150 - 200
Hard	over 200

Hard water can be further sub-divided into two types - **TEMPORARY** and **PERMANENT**. Temporary hardness can be removed by heating to temperatures above 60°C, whereas permanent hardness requires removal by chemical methods.
Temporary hardness can lead to the formation of scale deposits on heating pipes, boilers, kettles, etc.

PHYSICAL CHARACTERISTICS

Physical properties of water are relatively easy to measure and some are readily observable.

1. **TEMPERATURE** - this is important as it can have a marked effect on other properties - rate of chemical reactions, solubility, taste, etc.

2. **COLOUR** - pure water has a pale green-blue tint in large volumes. However, matter suspended in water can alter the apparent colour. The use of chlorination in water treatment will normally remove all traces of the original source colour.

3. **SOLIDS CONTENT** - solids may be present in suspension or solution or both. The larger suspended solids will normally settle out fairly quickly, whereas finer solid material may require the addition of chemicals to assist in their removal. The **turbidity** of water is the cloudy appearance due to the presence of very fine solids e.g., when clay and/or algae are present.

4. **TASTE** - pure water does not have a particularly pleasant taste, nor, frequently, does tap water as a result of the use of chlorine disinfectant. Water which contains quantities of naturally dissolved salts, on the other hand, can be quite pleasant and sweet tasting. On the other hand the presence of organic derived compounds (algae, peat) can lead to an unpleasant taste.

DISINFECTION

This process kills off harmful organisms in water so that infection by disease will not occur when the water is used for domestic purposes.
Generally this is achieved by chlorination that is the addition of chlorine into the water.
The organisms in water which it may be necessary to kill by disinfection include bacteria, viruses and protozoa.

The resistance of these organisms to the effects of disinfection varies according to the type of organism present.
Chlorine itself which is a very strong oxidising agent and its level of dosing must be strictly controlled otherwise the consumer will experience taste and odour problems in the supply. An alternative method of disinfection is by using ozone (O_3).

This is, however, a very expensive method if applied on a large scale.
The ozone must be produced at the point of treatment and its production involves the use of large quantities of electricity and its sterilizing effect is not as persistent as that of chlorine.
Disinfection is generally the last step in the treatment process.

OTHER FORMS OF WATER TREATMENT

The above methods of water treatment are a general guide to the steps which can be applied to obtain a potable water supply.
The quality of water and hence its treatment requirements can vary dramatically depending on for example the nature of the source. Therefore, there is not one standard system of water treatment. Each water will have its own requirements.
A few of the other possible types of treatment are mentioned briefly below.

(A) SOFTENING OF WATER

Hard waters are produced from a source where chalk or limestone is present.
Hard water causes a difficulty in obtaining lather with soap and will lead to a deposit forming in kettles or hot water pipes. The hard water may be softened by adding lime or sodium carbonate which will lead to a precipitate being formed which can be removed by filtration.

Alternatively the hard water may be passed through ion-exchange resins which will effectively remove the compounds which initially caused the hardness.

(B) IRON AND MANGANESE REMOVAL

Traces or iron and manganese can be found in many waters. Iron, while not being harmful in small amounts can impart a bitter taste to water and can cause brown stains to form on laundry. The presence of manganese can also cause taste problems and it can react with chlorine to produce an objectionable black slime.

A combination of chlorine and lime followed by filtration is now the common treatment for manganese removal.

(C) ADDITION OF FLUORIDE

The addition of **fluoride** to the water supply has been the subject of much public debate. It is now generally accepted that the addition of fluoride in small amounts to the water supply is effective in reducing dental cavities. Fluoride in the form of hydrofluorosilic acid can be added to the water after all other forms of treatment have been completed.

(D) TASTE, ODOUR AND ORGANIC REMOVAL

Activated (i.e., heat treated) carbon, either in powdered (PAC) or granular (GAC) form, is increasingly used in water treatment for taste, odour and organic removal.
It can be added (as PAC) at various treatment stages but the most common application is as filters containing GAC prior to the disinfection stage.

(E) PH CORRECTION

If necessary, e.g., in soft water areas, the pH of the water is adjusted by the addition of an alkali.
Lime and **calistic soda** can be used.
The purpose of pH adjustment is to make the water non-aggressive to metal pipework - both in the distribution network and in the home.

(F) NEW DEVELOPMENTS

New processes are being developed by the Water Industry e.g., sirofloc, membrane filtration.

The Sirofloc process uses finely divided magnetite to attract particulate (including collodial colour) material.
The magnetite itself is removed by a magnetic process.

SUMMARY

Water can be **softened** by several alternative methods; Base Exchange method, addition of lime-soda and use of **inhibitors**. In domestic installations the **Base Exchange** method is used and water is passed through a medium called 'zeolite', which converts the calcium salts in the water to sodium salts.

For industrial plant, water may be softened by the addition of **lime** or lime-soda. In this process large volumes of sludge needs to be removed.
Additives such as **'Calgon'** may be used to stop 'fur' in boilers and these may be regarded as inhibitors rather than true softeners.

Water contains dissolved and suspended **solids** which are small particles of animal and vegetable debris. Water from chalk or from salt-bearing strata may contain over 1000 p.p.m. (parts per million) solids, whereas water from upland sources may contain less than 50 p.p.m. (parts per million).

The water in treatment plants is **filtered** and **sterilised** with **'chlorine'** to reduce harmful effects of bacteria in water.

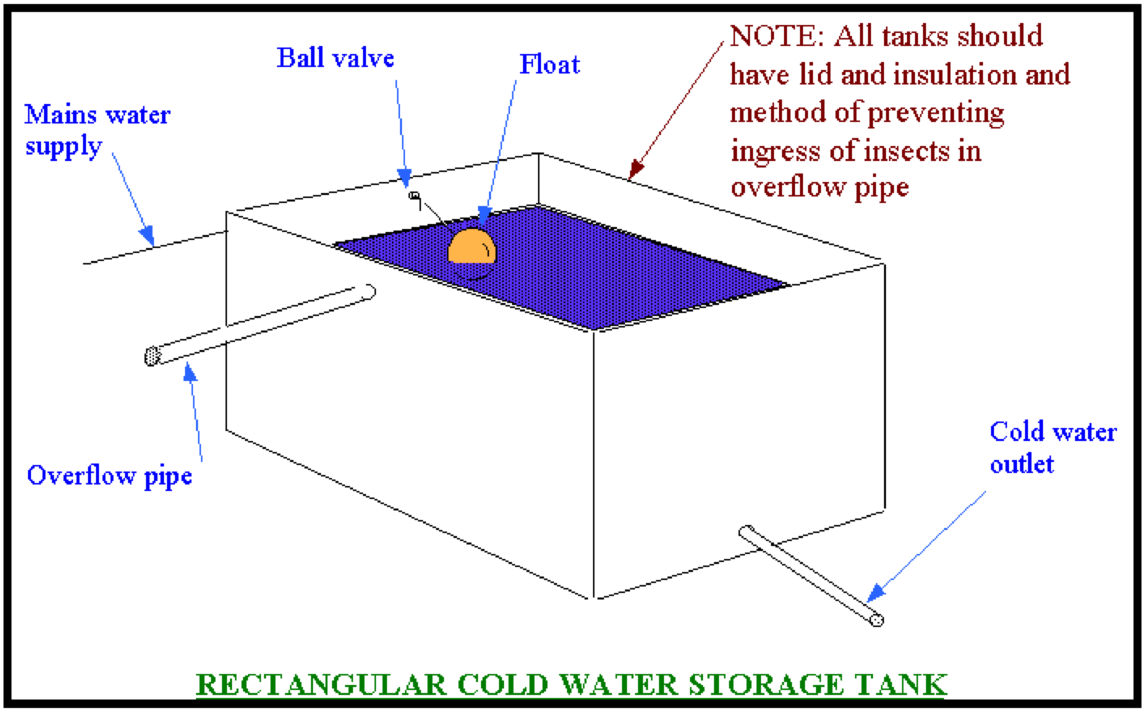
The **pH value** of water should be considered i.e. its acidity or alkalinity. Soft acid waters are derived from hard insoluble rocks or from peaty uplands, they have a pH less than **7.0** and may corrode pipes and tanks unless passed through a cylinder packed with limestone to neutralise the acidity.
Waters with a pH of more than 7.0 are alkaline and are not likely to attack metals.

COLD WATER STORAGE

Water storage in dwellings is usually required to meet a 24 hour demand, that is, if the supply is cut off, there will be a supply of cold water for 24 hours.
The consumption of cold water in any building depends upon;

- The use to which the water is put
- The number of consumers served.

The diagram below shows a typical water storage tank.



For domestic, as distinct from industrial usage, **storage requirements** per head of consumers are set out in Code of Practice (U.K.) CP310 and listed in the accompanying table A8 on the next page.

The practice of allocating storage per fitting or appliance is used less often since the water consumption depends more on the number of occupants than the number of appliances.

MATERIALS

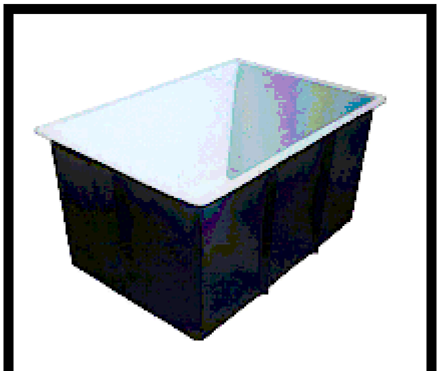
Plastic and GRP (Glass Reinforced Plastic) tanks are used for small installation such as in houses.

These are manufactured as a one piece item, therefore reducing the risk of leaks.

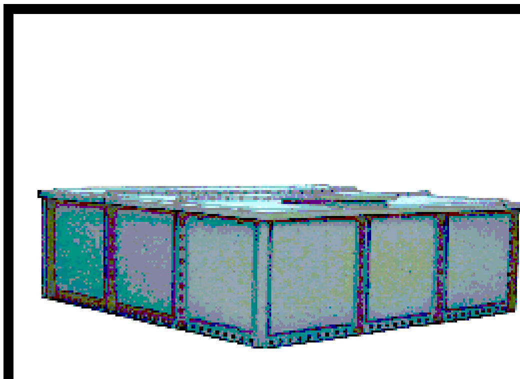
GRP (Glass Reinforced Plastic) and galvanised steel Sectional panel tanks are used for larger installations.

They are assembled on site with gaskets between panels and membranes inside to make them waterproof.

Glass-reinforced plastic (GRP) tanks should comply with BS7491 Parts 1, 2 and 3.



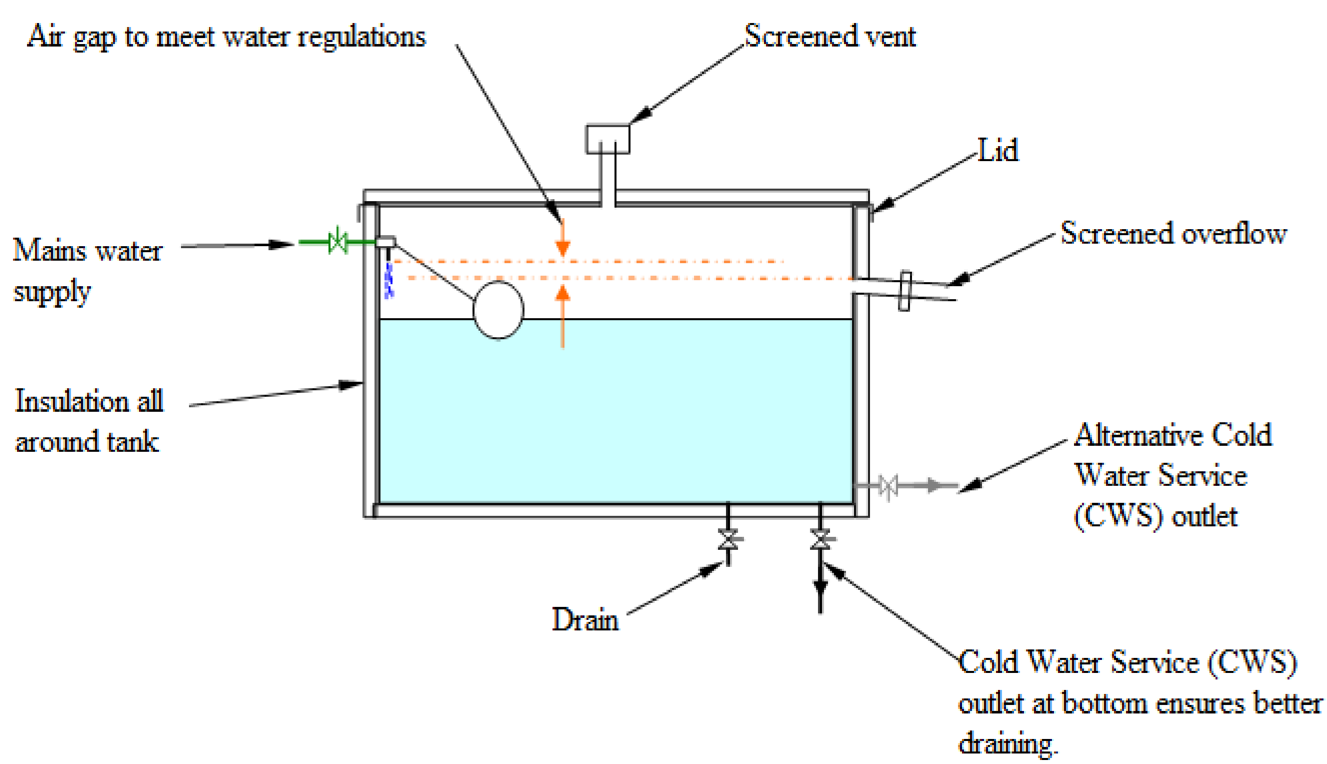
GRP One Piece Tank



GRP Sectional Tank

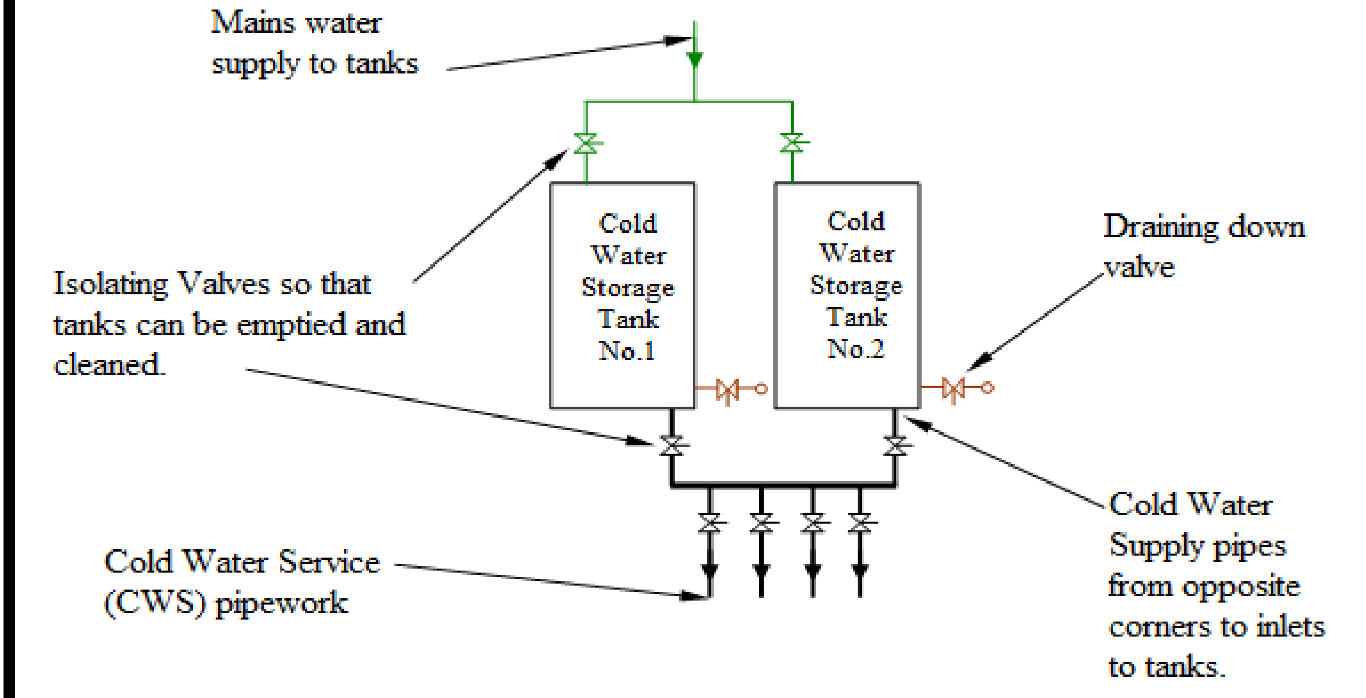
TANK INSTALLATIONS

A typical tank is shown below.



Typical Cold Water Storage Tank

It is important to have no stagnant areas in tanks and inlets and outlets should be at opposite ends to ensure a through flow of water as shown below.



Typical Cold Water Storage Tank arrangement

A balanced flow of water to and from tanks is recommended and this is achieved by installing inlets and outlets at the same level and with the same lengths of pipe work.

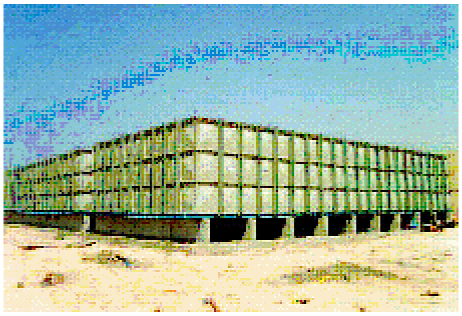
This ensures that the same amount of water enters each tank from the ball valve.

The tanks shown above are connected with a common outlet pipe or **manifold**.

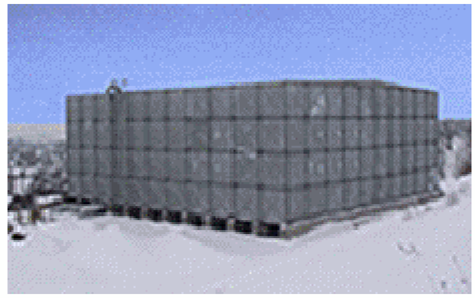
Each tank should have a **separate ball valve** and float arrangement and **separate overflow** discharge pipe.

Tanks should be periodically **cleaned** out to remove dust and grime build-up and a **valved drain** is used for this purpose.

The use of a delayed action float valve may also be considered to ensure a greater turn over of water.



Large Plastic Sectional Tank



Pressed Steel Sectional Tank

The Water Supply (Water Quality) Regulations permit cold water to be delivered at temperatures up to 25°C, although in normal circumstances it will be well below 18°C but the aim should be to keep the temperature below 20°C as far as is practicable to restrict microbiological growth.

This is achieved by insulating all tanks, pipe work, fittings and valves.

Tanks and pipe work are also insulated to reduce condensation.

Also all pipe work should be located away from warm areas such as plant rooms and warm roof spaces. Pipe work should not be routed through hot ducts or adjacent to heat sources, such as radiators and boilers.

CALCULATING COLD WATER STORAGE REQUIREMENTS

Public Health Engineering gives data for calculating cold water storage requirements for various buildings.

Table 2.2 gives 24 hour storage requirements based on various fittings, e.g. Shower 140-230 litres, Bath 900 litres, WC 180 litres, Basin 90 litres, Sink 90-180 litres, Urinal 110 litres.

Where water storage is to be located in each domestic dwelling, this should be provided by a cold water storage cistern mounted in the roof space or similar area with a storage to water line of at least 227-300 litres.

The cistern should be protected from frost and designed to maintain the water quality.

Table 2.3 gives recommended minimum Storage of Cold Water for hot and cold water services as shown below.

Type of Building	Storage per person (litres)
Hostels	90
Hotels	135
Offices with canteens	45
Offices without canteens	40
Restaurants, per meal	7
Boarding School	90
Day School – nursery/primary	15
Day School – secondary/technical	20
Children's home/ Residential nursery	135
Nurse's home	120
Nursing or convalescent home	135

BS6700 (2006) also gives Recommended minimum storage of cold water for domestic purposes (hot and cold outlets) in Table 1.

Example 1

In a house with 1No. Bath, 1No. Sink, 1No.basin, 1No. Shower and 1No.WC the cold water storage could be sized using Table 2.2 as detailed above.
Using minimum storage requirements for a 24 hour supply of cold water gives;
Bath = 900 litres, Sink = 90 litres, Basin = 90 litres, Shower = 140 litres WC = 180 litres.
Total = 1400 litres
These 1400 litres is too much storage for a house.

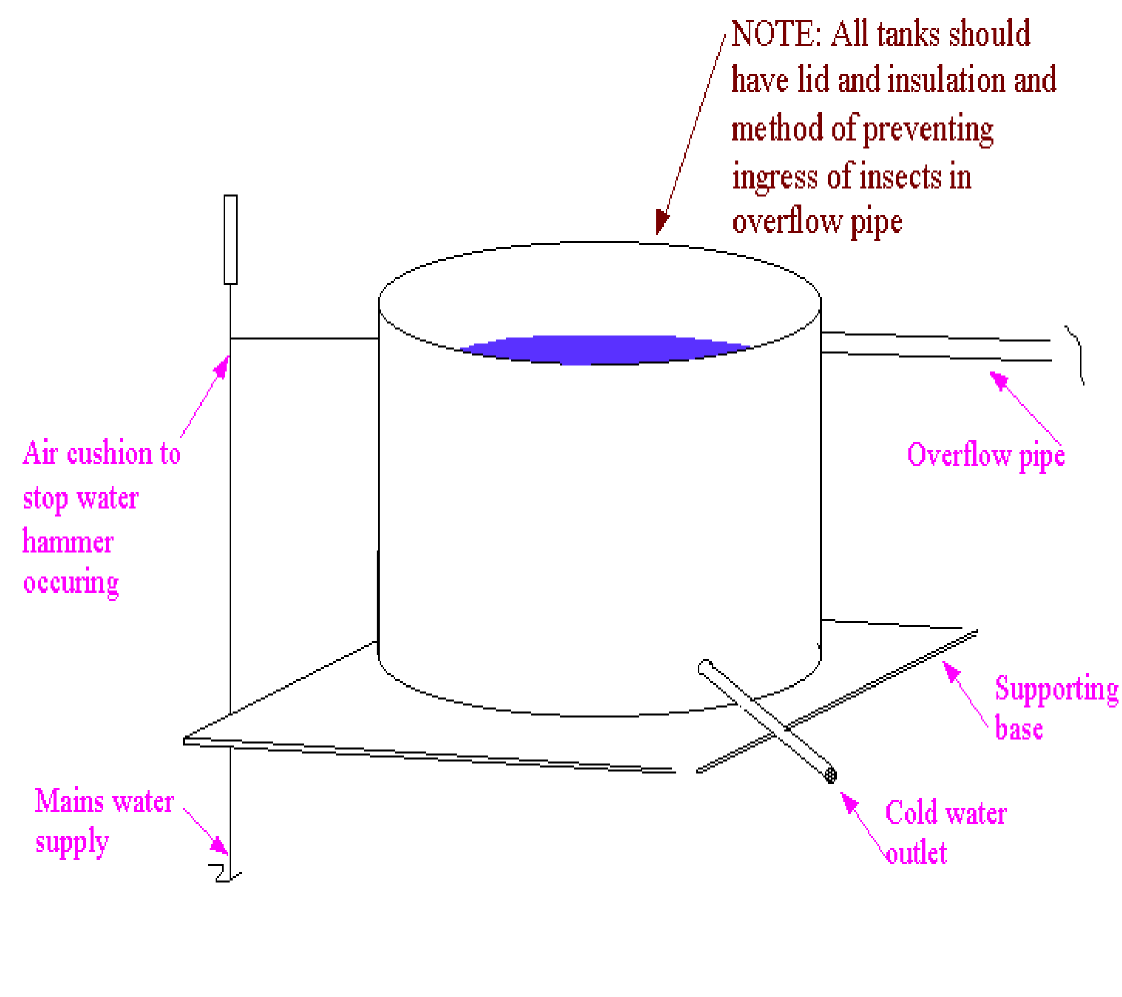
The older (1986) Table B4.2 gives storage at 90 litres per person in a house for 24 hours.
Storage required = 90 x 5 people = 450 litres

From Institute of Plumbing Guide Table A11, the nearest tank size is **SCM 680**, which has an actual capacity of 491 litres to the water line, **680** litres is the nominal capacity of the tank.

The dimensions of this rectangular tank are **1092mm x 864mm x 736mm** high.
Table A12 shows the equivalent tank as a circular Polythene or Polypropylene cistern.

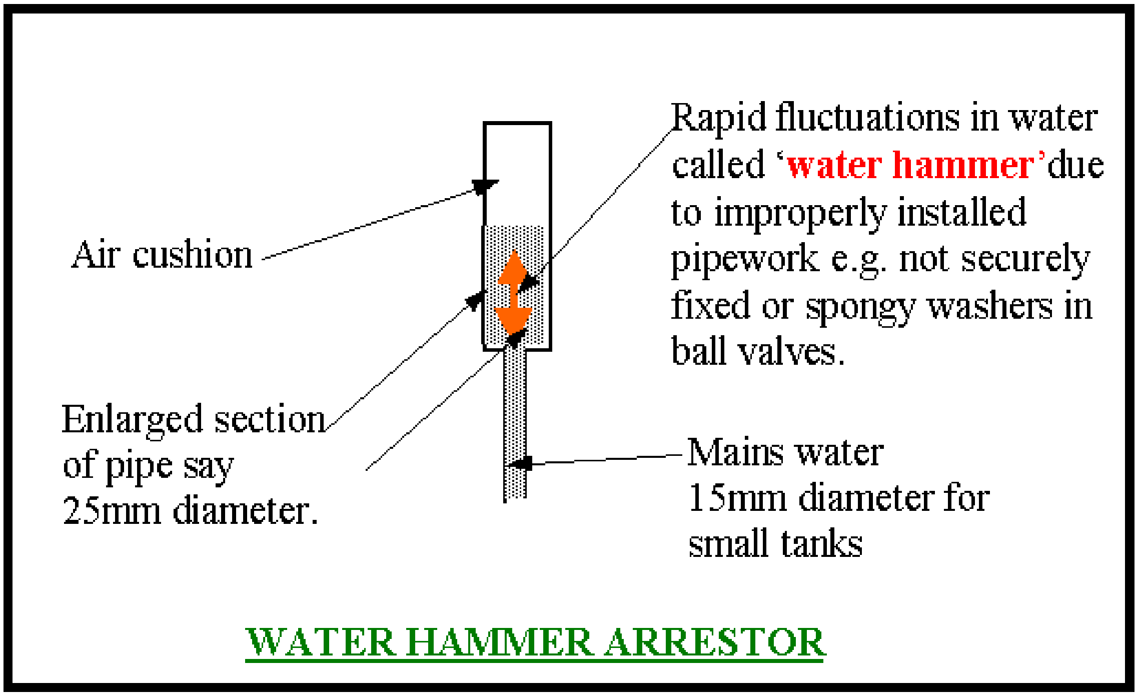
The cistern in this case would be PC 100 with an actual capacity of **455** litres and a height of 760mm.

The statement in Guide G (2004) section 2.4.3.1 gives domestic storage at **227-300 litres**.
A typical circular storage tank is shown below.



Circular Cold Water Storage Tank

An **air vessel** is shown in the above diagram on the mains water pipe to the tank. This is used to reduce water hammer as shown below



The consumption of cold water in buildings is based on the number of **occupants**.
For most dwellings cold water storage of **227 litres** capacity is sufficient.

EXAMPLE 2

To size the cold water storage tank(s) for a commercial/industrial building the method usually adopted is based on Table 2.3 in the CIBSE guide G (2004) as shown above.
For example for a **hotel** with a maximum of **50 occupants** the water storage would be:

135 x 50 = 6750 litres.

The largest galvanised steel tank capacity in the Institute of Plumbing guide table A11 is 3364 litres.

Therefore: **2No. Steel tanks of capacity each 3364 litres** could be used giving a total water capacity of: 2 x 3364 = 6728 litres

Each tank dimensions are (A11):
2438mm long x 1524mm wide x 1219mm high.

NOTE:

It is possible to have a non-storage system for cold water in a building although there would be no security of supply of cold water.

This means that there is no cold water storage tank in the building.
There would be no 24 hour storage capability so that if the water main was turned off, then WC's could not flush and other sanitary items would be inoperable.

This is only possible in a small building where the mains water system is secure and is not turned off regularly and water is not required for important reasons.
A non-storage system is not recommended for commercial buildings but has been tried in some domestic systems.

There are some advantages in not storing water in a building, one is that there is no risk of frost damage and another is that there is less risk of water borne bacterial growth.

HOT WATER GENERATION & STORAGE

Hot water is used for washing and cooking. The temperature required is about **45ºC.** Water is usually generated at a higher temperature (**55ºC to 65ºC**) in a vessel and mixed with cold water at mixing taps or mixing valves.

It is better to store water at a temperature much higher than body temperature (**37ºC**) to reduce risk of bacteria growth and other water borne **diseases.**

Hot water service systems may be divided into two main types:

1. Local systems

2. Central systems

Local hot water systems can be further subdivided into instantaneous heaters and storage heaters:

- **Instantaneous** - Electric type with output of between 0.02 litre/s and 0.05 litre/s, electrical loading from 3kW to 12kW.

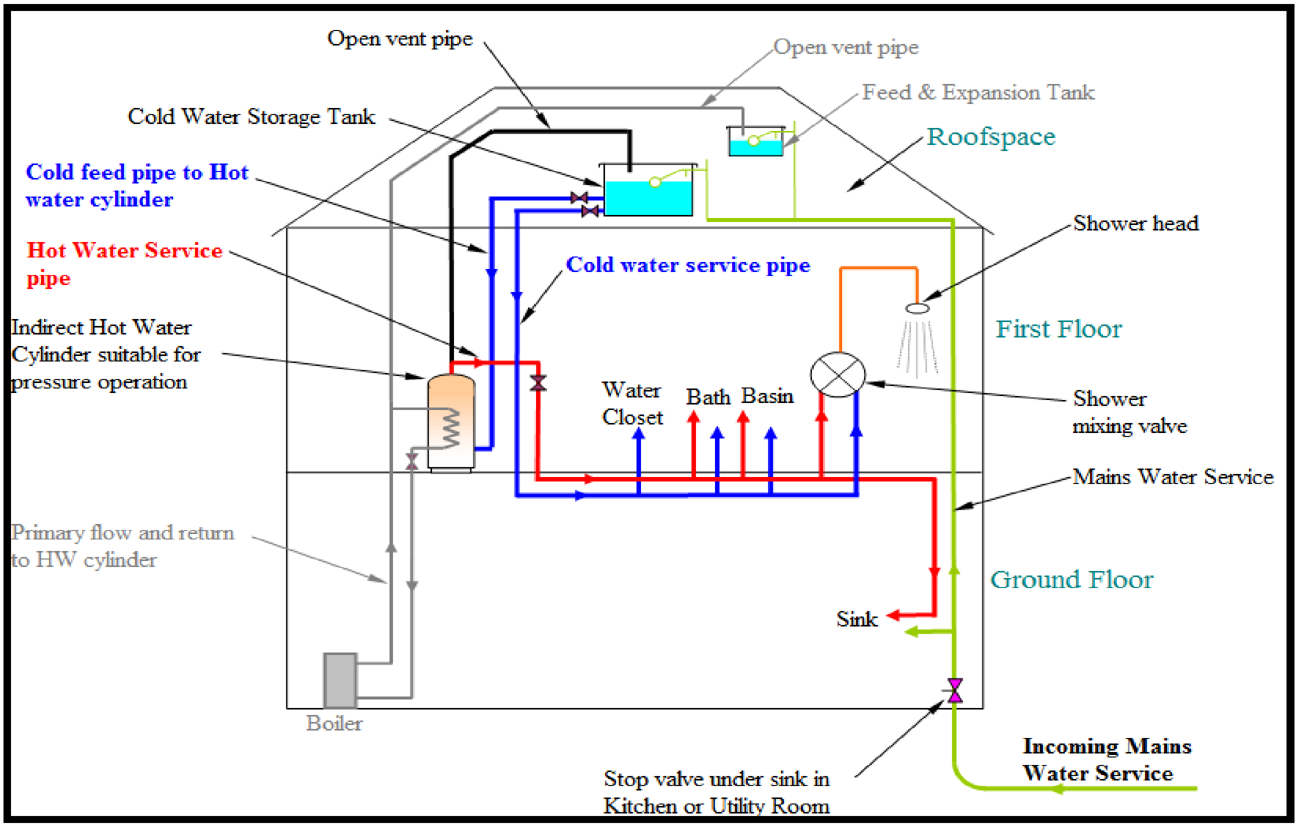
- **Storage cylinders** - for hot water - 7 to 70 litres capacity, with 3kW electrical heating elements.

CENTRAL SYSTEMS

Usually consist of a boiler or hot water heater coupled by circulating piping to a large storage vessel. The combination of the two will be so proportioned as to provide adequate service to the draw-off points, to match the predetermined pattern of usage.

For instance, in a **hospital** there may be a **continuous** demand for hot water all day and in this case a **small storage capacity with a rapid recovery period** (large boiler power) is probably appropriate. Conversely, for a **sports pavilion** where there may be a single sudden demand following a game, a **large storage capacity and a long recovery period** (small boiler power) may be adequate.

Most central systems use **indirect hot water cylinder(s)** since direct systems can require frequent cleaning as scale deposits build up inside boilers. When an indirect system is used the **primary and secondary** water systems have to be vented separately - primary water via. The feed and expansion (F & E) tank and secondary hot water via. The cold water storage cistern. A typical **DOMESTIC** system is shown below.



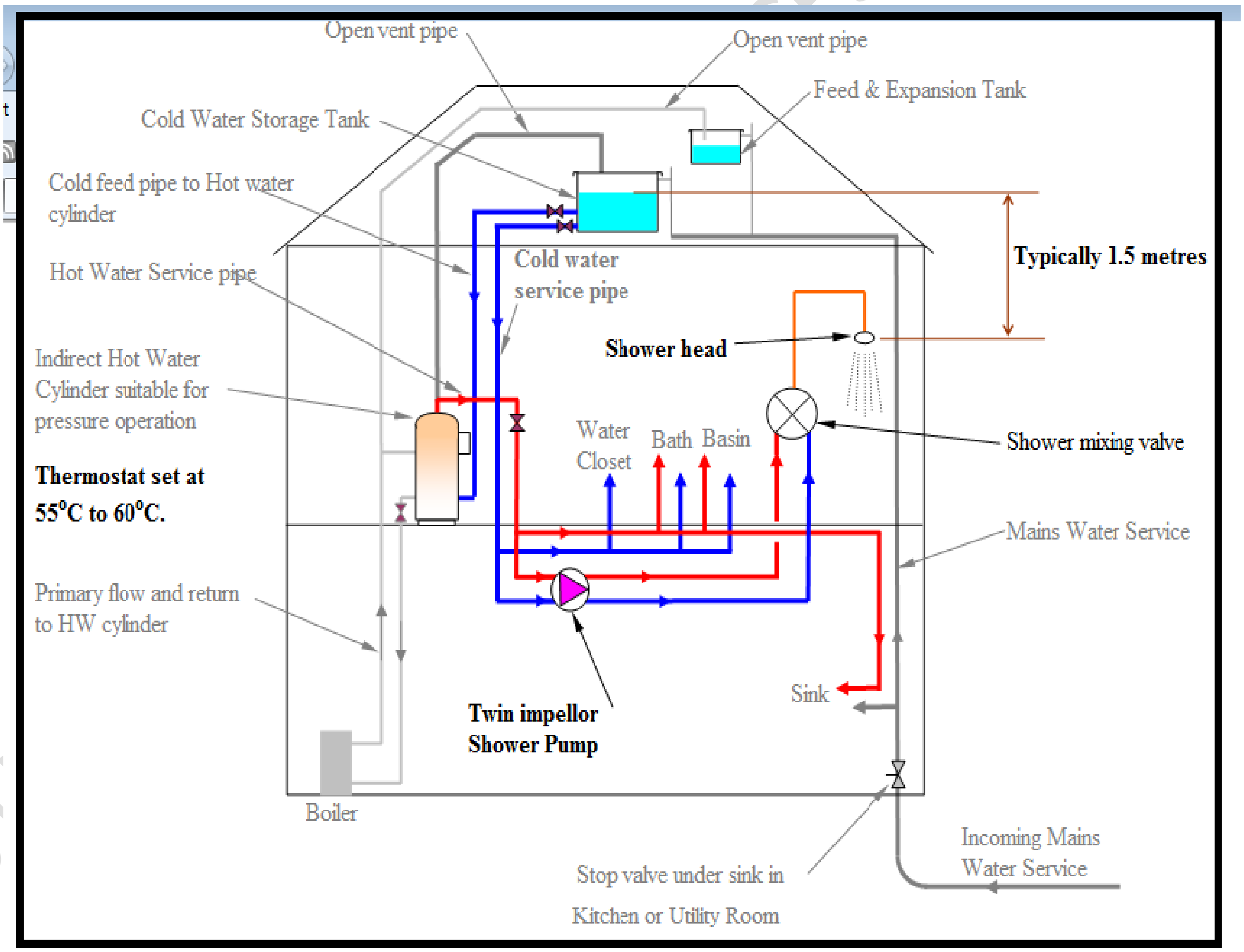
TRADITIONAL OR UN-PRESSURIZED HOT AND COLD WATER PLUMBING SYSTEM FOR A HOUSE

The above diagram shows an **indirect hot water cylinder**, known as indirect because the hot water from the boiler (primary circulation) doesn't come into direct contact with the hot water in the cylinder (secondary circulation) - this water being used for washing and cooking.

The hot water cylinder, indirect coil and pipe work are made of copper.
It is feasible to use 'plastic' pipe work for this and **poly butylene** is more frequently installed especially in concealed locations.

A **vent** is required on the hot water outlet pipe at the top of the cylinder to allow for water expansion and prevent the cylinder becoming pressurised when heated.

The **temperature of water** in the cylinder must be controlled in accordance with the building regulations. See CONTROLS section.
This is achieved by an immersion thermostat in the cylinder or clamp-on thermostat either switching on and off a pump or control valve.
An alternative method of control is to use a thermostatically controlled valve which has the sensing head on the cylinder.



UN-PRESSURISED HOT AND COLD WATER PLUMBING SYSTEM WITH SHOWER PUMP

Since the water flow from the shower head relies on the head of water between the tank water level and the shower outlet, then there will be inadequate flow in a first floor shower.

There are two methods used in domestic installations to overcome poor water flow at showers;

- **Pressurise** the whole hot water system (See Pressurised Domestic Hot and Cold Water Systems).
- Install a **shower pump**; this is installed on the Hot Water Service (HWS) and Cold Water Service (CWS) to the shower mixing valve.

A separate shower pump can be installed in the roof space or hot press, or a combined unit including mixing valve can be installed in the shower area. Usually the cheaper option since pressurised cylinders cost up to 6 times more than un-pressurised cylinders.

HOT WATER CYLINDERS

Hot water is stored in copper cylinders in domestic premises. In larger installations thicker wall copper cylinders can be used or copper lined steel cylinders.

Thin wall copper cylinders cannot withstand much pressure so stainless steel vessels are used for pressurised water systems.

The photographs below show some alternative cylinders for domestic hot water storage.

Pressurised Hot water Cylinder
Also known as Un-Vented Cylinder)

Another way to categorise hot water systems is as storage or non-storage systems.

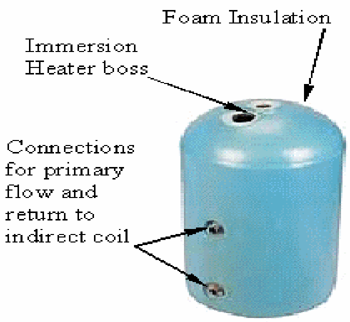
Storage systems are;

An indirect hot water cylinder as shown above.
A Direct gas or oil-fired storage vessel.
An electrically heated storage vessel

Pressurised cylinder installed

Non-storage systems are;

Central heating Combination Boilers that supply instantaneous hot water on demand.
Plate Heat Exchangers that are used for large demands of hot water.
Instantaneous water heaters; gas or electric.
Shell and Tube Heat Exchangers store some hot water but are used primarily for quick heat up.



Standard Indirect Hot Water Cylinder

CALCULATING HOT WATER STORAGE REQUIREMENTS

Domestic hot water cylinder capacities should be calculated in accordance with BS 6700. The storage water temperature should not exceed 65ºC.

In domestic dwellings the storage capacity should normally be based on **45** litres per occupant, and 200 litres for off-peak electric installations.

The amount of hot water to be stored in a cylinder is found from information in the guide G Section 2 (2004) Table 2.7 and 2.8.

For domestic installations a cylinder of approximately 120 litres capacity is usually adequate.

Also BS6700 (2006) gives data for Hot Water storage requirements in section 5.3 - Hot Water services.

The following Table includes information from BS6700.

Domestic Appliances / Dwelling	Hot Water requirement
Hot Water (60°C) used in dwellings	35 litres to 45 litres per person per day
Average bath	60 litres at 60°C plus
	40 litres at 10°C plus
	100 litres at 40°C plus
Shower	0.05 l/s to 0.15 l/s at 40 °C
Power shower	Up to 0.20 l/s at 40°C to 60°C
Wash basin hot tap	0.10 l/s to 0.15 l/s at 40°C
Kitchen sink	0.10 l/s to 0.20 l/s at 60°C

CALCULATING BOILER POWER REQUIRED TO HEAT A HOT WATER CYLINDER

The amount of heat required from boiler plant is:

H = m x Cp x (t_{hot} - t_{cold}) / Hours heat up x Efficiency x 3600

Where;	**H**	**=**	**Heat required or Boiler Power (kW)**
	m	**=**	**Mass of water in cylinder (kg). 1kg of water = 1 litre**
	Cp	**=**	**Specific heat capacity of water (4.187 kJ/kg degC)**
	t_{hot}	**=**	**Hot water temperature (about 60^{o}C)**
	t_{cold}	**=**	**Cold feed water temperature usually taken as 10^{o}C**
	Hours heat up	**=**	**Allow 1.5 to 3 hours for a standard cylinder to heat up.**
	Efficiency	**=**	**usually taken as 0.9 since hot water cylinders are insulated.**
	3600	**=**	**To convert hours to seconds.**

EXAMPLE 1

Calculate the boiler power required to heat a 120 litre hot water cylinder in 1.5 hours.
The hot water temperature is 60^{o}C and the cold feed temperature is 10^{o}C.

H = m x Cp x (t_{hot} - t_{cold}) / Hours heat up x Efficiency x 3600

H = 120 kg x 4.187 x (60 - 10) / 1.5 x 0.9 x 3600

H = **5.17 kW**

Example 2

Calculate the boiler power required to heat a 120 litre hot water cylinder in 1.5 hours.
The hot water temperature is 55°C and the cold feed temperature is 10°C.

H = m x Cp x (t_{hot} - $t_{cold)}$ / Hours heat up x Efficiency x 3600

H = 120 kg x 4.187 x (55 - 10) / 1.5 x 0.9 x 3600

H = **4.65 kW**

Example 3

Calculate the boiler power required to heat a 500 litre hot water cylinder for a Nursing Home in 2.0 hours.
The hot water temperature is 65°C and the cold feed temperature is 10°C.

H = m x Cp x (t_{hot} - $t_{cold)}$ / Hours heat up x Efficiency x 3600

H = 500 kg x 4.187 x (65 - 10) / 2.0 x 0.9 x 3600

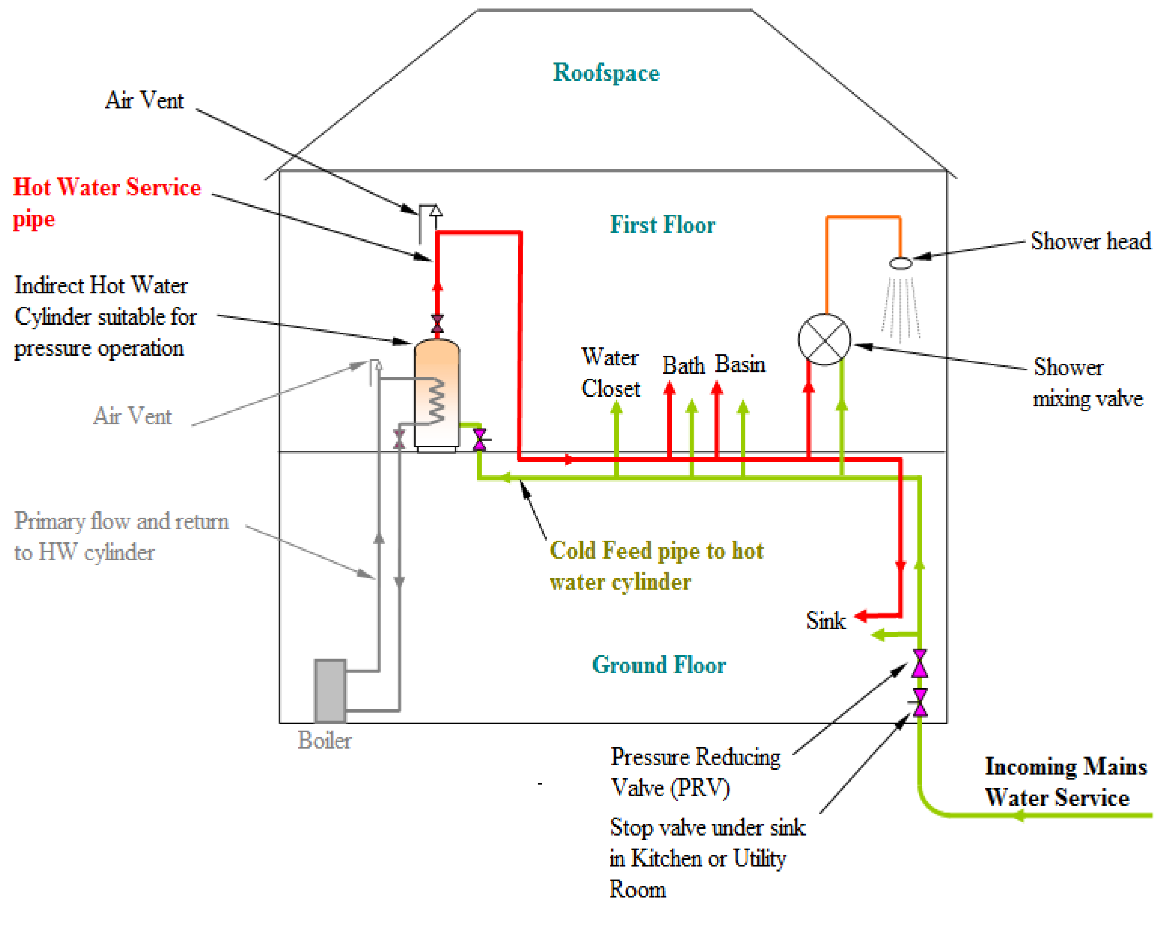
H = **17.77 kW**

PRESSURISED DOMESTIC HOT & COLD SYSTEMS

To provide adequate pressure of hot and cold water at sanitary appliances (particularly showers) an unvented system is used.

PRESSURISED HOT SYSTEM

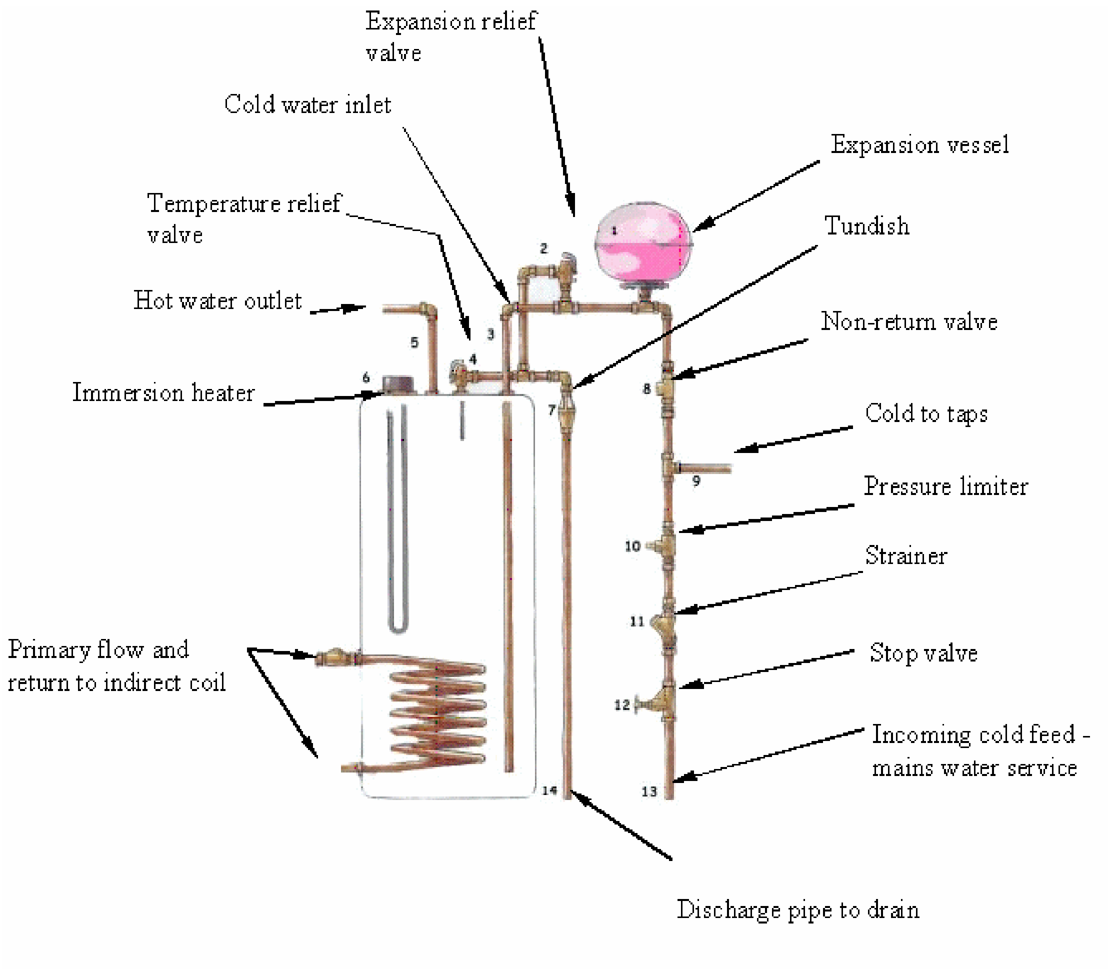
For pressurised hot water supply this can be provided by a Combination boiler (see Heating section) or by a pressurised cylinder as shown below. This is sometimes called an unvented hot water system.



Pressurised or Unvented Hot and Cold Water Plumbing System for a House

The pressurised hot water cylinder has a conventional indirect coil inside to heat water for washing and cooking from a boiler. The cylinder needs to be able to withstand an increase in water pressure compared to un-pressurised system. This means that the cylinder is really a stainless steel pressure vessel tested to withstand twice normal working pressure.

An expansion vessel is also required to accommodate the expansion volume as water is heated from 10ºC to about 65ºC. This expansion vessel is sometimes incorporated into a casing which includes the cylinder and insulation. A typical pressurised cylinder is shown below.



Pressurised Hot Water Cylinder

PRESSURISED COLD SYSTEM

There is no difficulty providing pressurised cold water in a house since the mains system can be used and piped via. A pressure reducing valve (PRV) to sink, bath, basin, shower and w.c. This is shown above in the diagram; Pressurised or Unvented Hot & Cold Water Plumbing System for a House.

The **Pressure Reducing Valve (PRV)** is essential to reduce the pressure from about 3 bars to 1.5 bars. This is sufficient pressure to operate domestic sanitary appliances, if the pressure is too high there is more chance of leaks, more water is used and water may spray back from basins.

ISOLATION

It is always good practice to install isolating valves at each sanitary appliance for both hot and cold services. This means that local maintenance can be carried out easily. Inexpensive quarter turn ball valves can be used.

COLD WATER TO HIGH RISE BUILDINGS

If the head of water in the main is not sufficient to supply water to the top floors of high rise buildings, then it will probably be necessary to pump water to the top of the building. The head of water which is available in the mains can easily be calculated by using the following formula:

$$p = \rho \times g \times h$$

Rearranging gives;

$$h = p / (\rho \times g)$$

Where;

p = Water pressure (N/m^2 or Pa)
To convert from bar pressure – 1 bar = 100,000 N/m^2 or Pa.

ρ = Density of water (1000 kg/m^3)

g = Acceleration due to gravity (9.81 m/s^2)

h = Head (m)

EXAMPLE 1

For water pressure of 3.4 bar the equivalent head would be;

$$h = p / (\rho \times g)$$

$$h = 3.4 \times 100{,}000 / (1000 \times 9.8)$$

$$h = 34.66 \text{ metres}$$

This means that the water main is capable of delivering water to a height of 34.66 metres. There would be no flow of water from a pipe at this height and we have not taken pipe and fitting resistance into account.

To overcome these difficulties a water pressure boosted system is necessary.

For an approximate conversion from bar pressure to head multiply by 10.

Example 2

Calculate approximately the head of water in a reservoir if the pressure is 4 bar.

Answer: 4 bar x 10 = 40 metres head approximately.

This can be compared to the accurate answer which is; 40.775 metres.

PRESSURE BOOSTING

Pressure boosting equipment can be divided into three categories:

1. The pneumatic system, as shown on the following page is essentially pressure controlled.

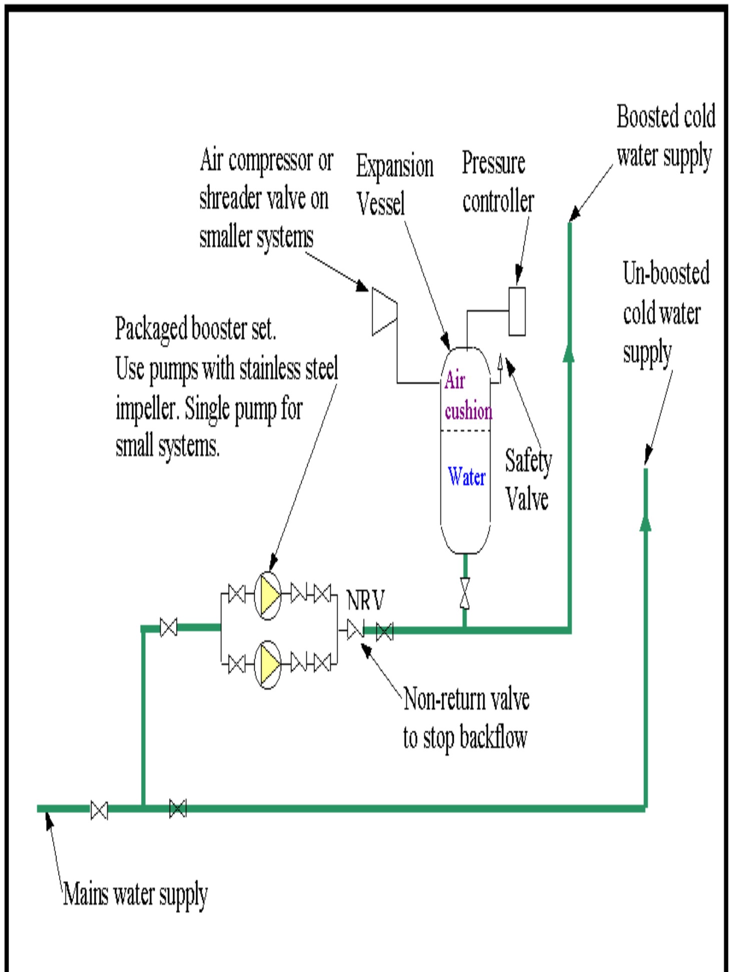
2. The intermittent pump system which is essentially float switch controlled.

3. The continuously running pump system which is a useful application for smaller systems and relies for its control upon careful choice of pump characteristic and a small pressure bleed from delivery to suction.

COLD WATER TO HIGH RISE BUILDINGS

PNEUMATIC BOOSTING

A typical pneumatic cold water boosting system is shown below.

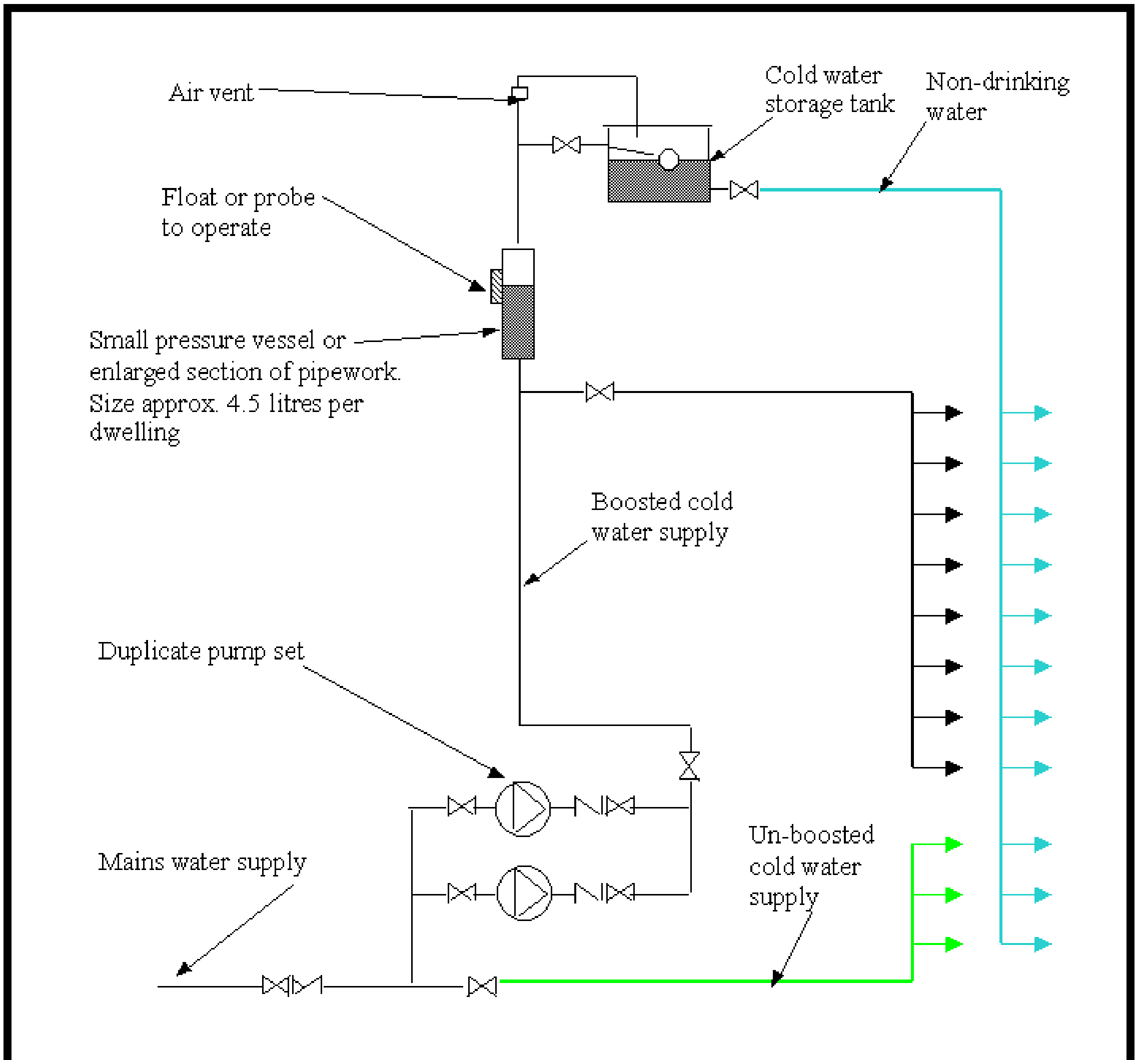


PNEUMATIC BOOSTING FOR COLD WATER SYSTEM

In the **pneumatic** boosting system a cushion of air under pressure is maintained in the top of a pressure vessel. When a tap is opened the air is able to expand by forcing the water out of the cylinder and through the pipe work. This process can continue until the water level drops to a predetermined point, when the pumps will be switched on to raise the level again. Drinking water is drawn off from the pressure vessel, although the drinking water can be supplied direct to lower floors where the mains pressure is sufficient.

In the boosted water system, precautions are taken to ensure purity of water.
The air pumped in, is filtered to prevent dust and insects gaining access and the capacity of the vessel is kept reasonably small to prevent stagnation - **viral diseases** can spread when **bacteria** are allowed to multiply in humid, stagnant and warm conditions.

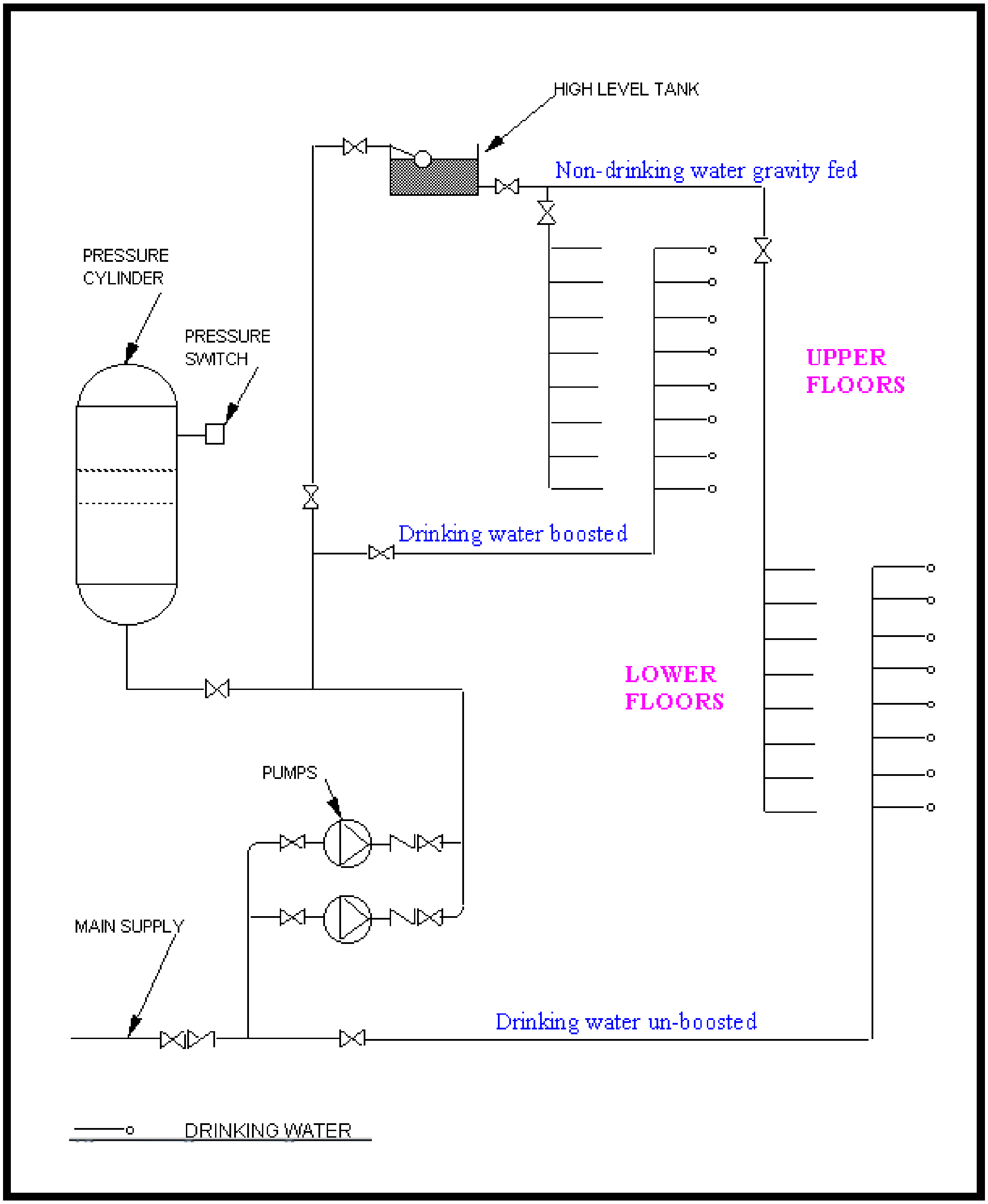
For dwellings, the volume of water between high and low levels would typically be no more than **4.5 litres** per dwelling. For flats of about 15 floors a simplified system is possible as shown below. The system below differs from the previous design, principally in that minor drinking water is supplied by means of an enlarged section of pipe above the level of the highest flat. This enlarged section allows water to flow to drinking water taps without the pump being operated until the section becomes empty.



SYSTEM FOR RAISING WATER TO FLATS

For buildings higher than about 10 storeys it is necessary that consideration be given to pressure balancing at individual draw-off fittings by means of orifice plates or by arranging the piping system in vertical zones with reducing valves.
For very high buildings, the provision of intermediate water storage and further pumping equipment may be necessary.

The drawing below shows a typical boosted cold water system for a high rise building such as a block of flats or apartments.



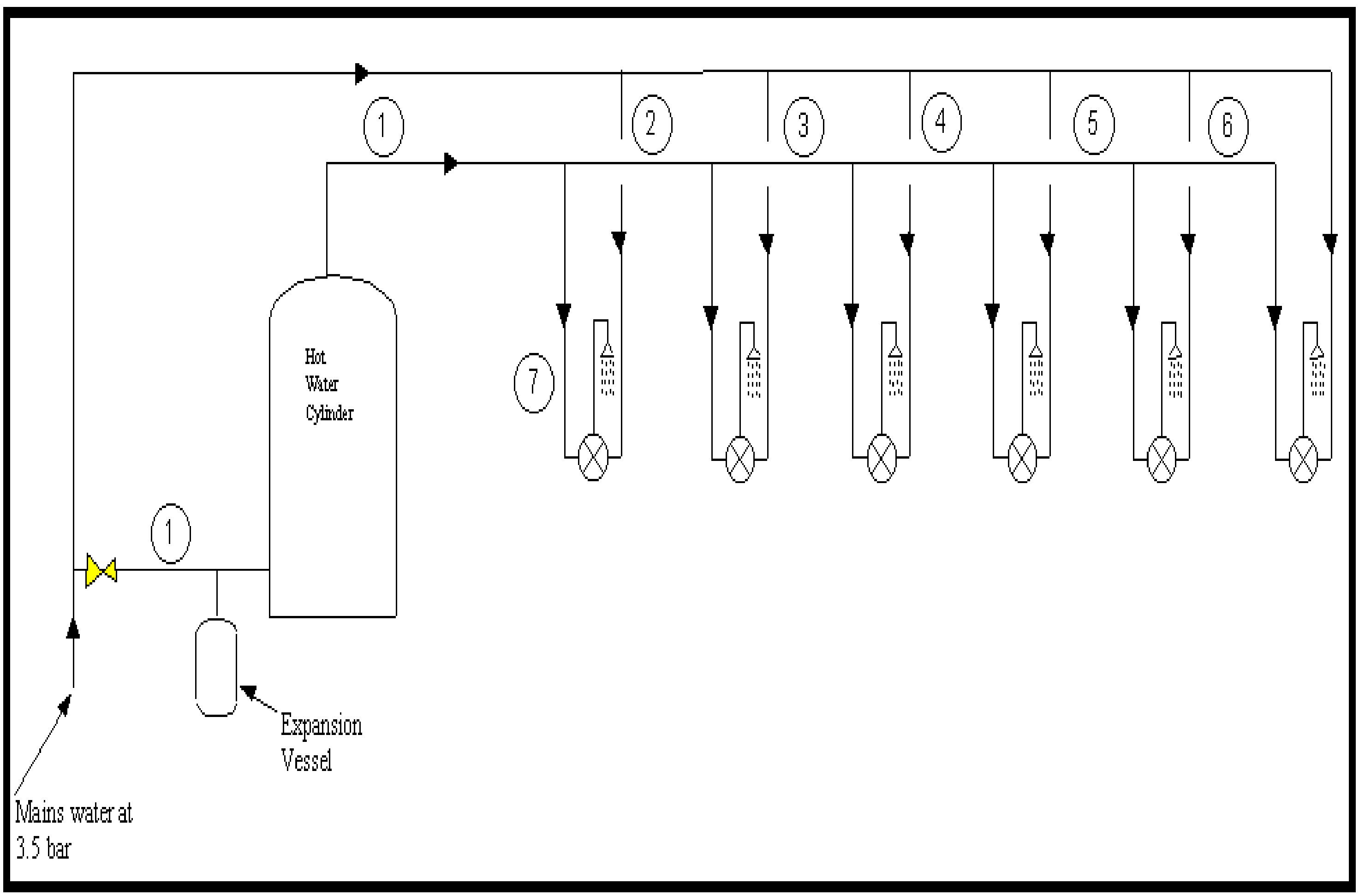
PRESSURISED COLD WATER SYSTEM FOR HIGH RISE BUILDING

HOT WATER SYSTEM PRESSURISATION

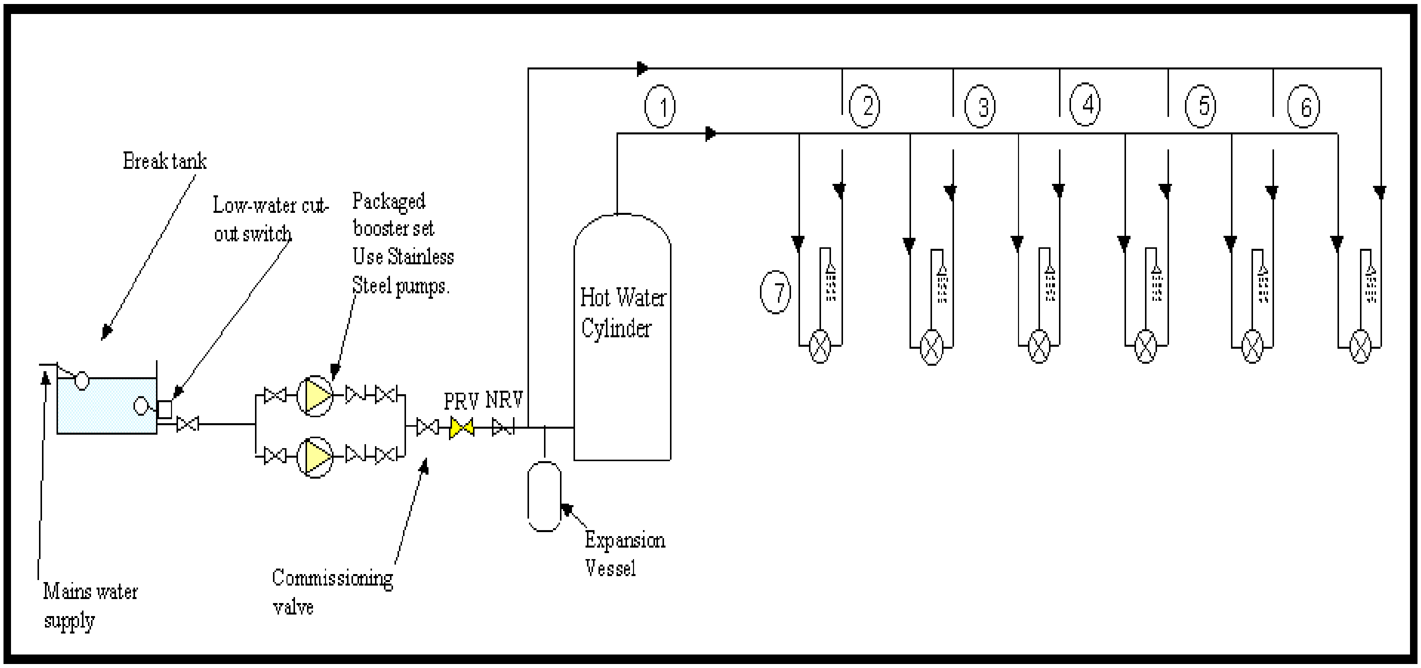
The following systems can be used to produce pressurised hot water in Commercial buildings.

- Use a pressurised hot water cylinder similar to the Domestic Pressurised system as shown below.
- Use a pumped or boosted system as shown below.
- Use a plate heat exchanger (see Heat Exchangers in Thermo fluids section of the notes).

The diagram below shows a Hot Water pressurised system using showers, pressurised from the Mains Water feed.



An alternative system using Booster pumps is shown below.



NOTES ON SYSTEM DESIGN

- The Building Reg. G3 (English) requires packaged units to be BBA certified.
- Pressure safety valve to be factory set.
- Fit Non Return Valve (**NRV**) on Mains Water Service (MWS) supply to avoid back-flow.
- Increase in volume is about 4% when water is heated.
- Expansion relief valve and temperature relief valves should have drains.
- Expansion relief should not open under normal conditions.
- A **high temperature** cut-out automatically shuts off the primary heat source. Set **at 95 ºC**
- Temperature and pressure relief set at **95ºC.**
- Discharge from relief valves must be in a visible location preferably outside the building, with a continuous fall, max. Length 9 metres.
- An in-line anti-vacuum valve is recommended.
- System high and low pressure cut-out switches are essential and should be connected to boiler controls to switch off boiler.

SIZING COMMERCIAL HOT WATER SYSTEMS

Larger hot and cold water systems will invariably be pressurised by one of the methods previously described in the Commercial Cold Water section of the notes..
Pipes may be sized using the normal pipe work data.

EXAMPLE 1

Size and design the HWS pipe work and equipment in the system shown below.
Building Data: The building is a Sports Hall – the area is the Shower block.
Information given:

1. Calorifier catalogue: Albion
2. Diaphragm vessel catalogue: Brefco
3. A guide to Sealed Systems:
   SEVA (Sealed Expansion Vessel Association)
4. 4. Shower catalogue: Mira 415

SUGGESTED DESIGN PROCESS

1. Choose system operating pressure from cylinder catalogue and shower catalogue.
2. Choose cylinder type.
3. Size Hot Water Cylinder (Calorifier)
4. Size Primary LTHW F & R pipes.
5. Size Hot Water Service (HWS) pipe work
6. Put all pressures on drawing.
7. Decide on Maximum Working Pressure, or pressure relief valve setting.
8. Calculate system water content.
9. Size Expansion Vessel
10. Complete drawing.

HOT WATER CYLINDER PRESSURE

From shower catalogue (MIRA 415) the flow rate from the mixing valves is to be: 9 litres/minute @ 1.0 bar pressure.

Choose Albion Class, Working head = metres = bar pressure

Say **Operating Pressure** inside cylinder is bar.

Hot Water Cylinder Size

From shower catalogue (MIRA 415) the flow rate from the mixing valves is to be: 9 litres/minute @ 1.0 bar pressure.

It is assumed that all showers will be operating simultaneously.

Assume recovery time for cylinder is 1 hour.

Each shower session last 10 minutes.

Also there will be 20 minutes between showering sessions.

Total flow rate of HWS from cylinder is: 9 l/min. x 6 No. = 54 l/min.

If the average showering session lasts 10 minutes then: 54 l/min x 10 mins=540 litres

There will be two shower sessions per hour.

Total storage required = 540 litres x 2 = **1080 litres.**

This water will be generated at 60-65ºC and water for showering may be required to be about 45 ºC, thus 70% of the water at 60ºC may be mixed with 30% of cold water at 10ºC.

60	-	45	=	15		
45	-	10	=	35		
15	/	50	=	0.3	=	30%
35	/	50	=	0.7	=	70%

The hot water cylinder capacity is therefore:

1080 litres x 70% =**756 litres**

It is worth noting that if the recovery time can be halved then the hot water cylinder size is also halved. Recovery time depends on the primary coil output.

Albion catalogue gives: Ref No. Capacity litres, Dimensions:

Primary Heat Output and Flow Rate:

$$H = \frac{m \times Cp \times \delta T}{Hrs_{recovery} \times \eta \times 3600}$$

$$H = \frac{\times 4.2 \times (60 - 10)}{1.0 \times 0.9 \times 3600}$$

$$H = \quad Kw$$

Primary Flow rate $m = {}^{H}\!\big/\!_{(Cp \times \delta T)}$

$$m = \quad /_{42} \quad = \quad kg / s$$

Pipe size for Primary flow and return is therefore: (Based on max. pressure drop of 300 Pa / m.) From pipe sizing Table C4.14, a pipe size of would be suitable.

EXPANSION VESSEL SIZE

System water content: Use the table below to determine the total system water content. Pipe work:

Pipe dia. (mm)	Flow rate Litres/min	Length (m)	Litres water content (l)
15			
20			
25			
32			
40			
50			
		Total	

Cylinder content = litres

Total system water content = litres

Acceptance factor = (Max. working pressure – Minimum incoming pressure) / max working pressure

Acceptance factor =

Vessel size = (System water content – Expansion coefficient) / Acceptance factor.

Vessel size = litres

PREVENTING DEAD LEGS IN HOT WATER SYSTEMS

Dead legs occur in hot water systems where water does not move for a period of time. The most common time for dead legs to occur is at night when hot water is not used and the contents of the pipes and appliances cools down. When the hot water outlets are turned on the following morning then the cooler water is drawn off before hot water reaches the outlet. This could take some time if long runs of pipe work are involved.

Another difficulty with dead legs is that when water cools to 20ºC to 45ºC it becomes more susceptible to bacteria growth, and overnight gives adequate time for possible bacteria to multiply. This happens even if the pipe work is insulated.

To avoid dead legs in plumbing systems there are two common approaches;

1. Install a secondary return pipe.
2. Maintain the water temperature at all times with trace heating.

PREVENTING BACTERIAL GROWTH

Bacteria can be found everywhere and when they multiply can cause harm.
The following can lead to significant colonisation and should be avoided:

- dirt, scale, rust, algae, organic particulates and sludge in cisterns and calorifiers
- Storage and/or distribution temperatures in the range 20-45oC.
- Large volumes of static water or small ratios of water use to system volume.

LEGIONELLOSIS

- Legionella is associated with respiratory tract infections in humans. The disease is called legionellosis.

The severity of the disease ranges from Legionnaires’ disease, an acute severe pneumonia, to Pontiac fever, a mild non-pneumonic, flu-like infection.
Legionella pneurnophila serogroup 1 is the most common cause of human infection.

LEGIONELLA LOCATIONS

The Public Health Laboratory carried out a study of the presence of Legionella in water systems and found Legionella in 60% of all man-made water systems. This is a striking result and shows that engineers should not be complacent when designing water systems.

Places at risk are; cooling towers, hot water systems, whirlpool spa baths, and clinical humidifiers in respiratory equipment, supermarket vegetable sprays, natural spa baths, fountains and potting compost. In Britain almost all of the major Legionella outbreaks have been associated with cooling towers and large domestic water systems.

CONDITIONS FOR SURVIVAL AND GROWTH

Temperature is the most important factor in the survival and growth of Legionella.
The micro-organisms can grow at temperatures between 20-45oC, the optimum temperature for growth and virulence being 36oC. Legionella can survive at temperatures below 20oC but it can’t grow, and at temperatures above 60oC Legionella are rapidly killed.

Humidity is also an important factor considering the ability of Legionella to survive in aerosols. As the humidity increases the ability of Legionella to survive increases.

The nutrients available in water systems from plumbing materials or organic matter may also increase Legionella growth.
Bio film formations in water systems provide protection from adverse conditions like biocide concentration and shear forces of water. Moreover the presence of other micro-organisms will, depending on the type present, increase the ability of Legionella to survive.

COLD WATER STORAGE SYSTEMS AND TANKS

Cold water storage tanks and pipes should store water at below 20°C.
Cold water storage systems and tanks should be flushed, tested and disinfected where necessary before bringing into use as required by ‘The Water Supply (water fitting) Regulations1999’. All cold water storage systems and all storage tanks should be thoroughly cleaned out at least annually.

If continuous disinfection is used, an official logbook should be maintained and the readings of disinfection effectiveness in the cold water storage system recorded daily. At least once a week the Maintenance Team should examine and sign the log book and in the event of the disinfection levels falling below the minimum effective levels take appropriate action.
Planned Preventive Maintenance system of daily inspections of the chlorination plant.

TESTING OF OUTLETS

During one week in each year, a thorough test of very hot and cold water outlet, including all thermostatic mixing valves etc should take place and a suitable log retained. In the case of cold water outlets these should indicate between 1 -2mg/l chlorine strength within one minute of running the waste.

In the case of hot water outlets these should indicate temperatures of between 50-60°C within one minute of running to waste. If connected to a dosing pump, 1 -2mg/l chlorine strength should be achieved.

All thermostatic mixing valves, shower heads and spray taps etc. should be tested by first running hot water to waste without recording temperatures for a minimum of one minute, then running cold to waste, when a chlorine strength of between 1-2mg/l chlorine strength should be achieved.

AIR CONDITIONING PLANT

Wet cooling towers should be replaced by air to water or air cooled condensers. Humidifiers should be steam type rather than water spray.

SUMMARY

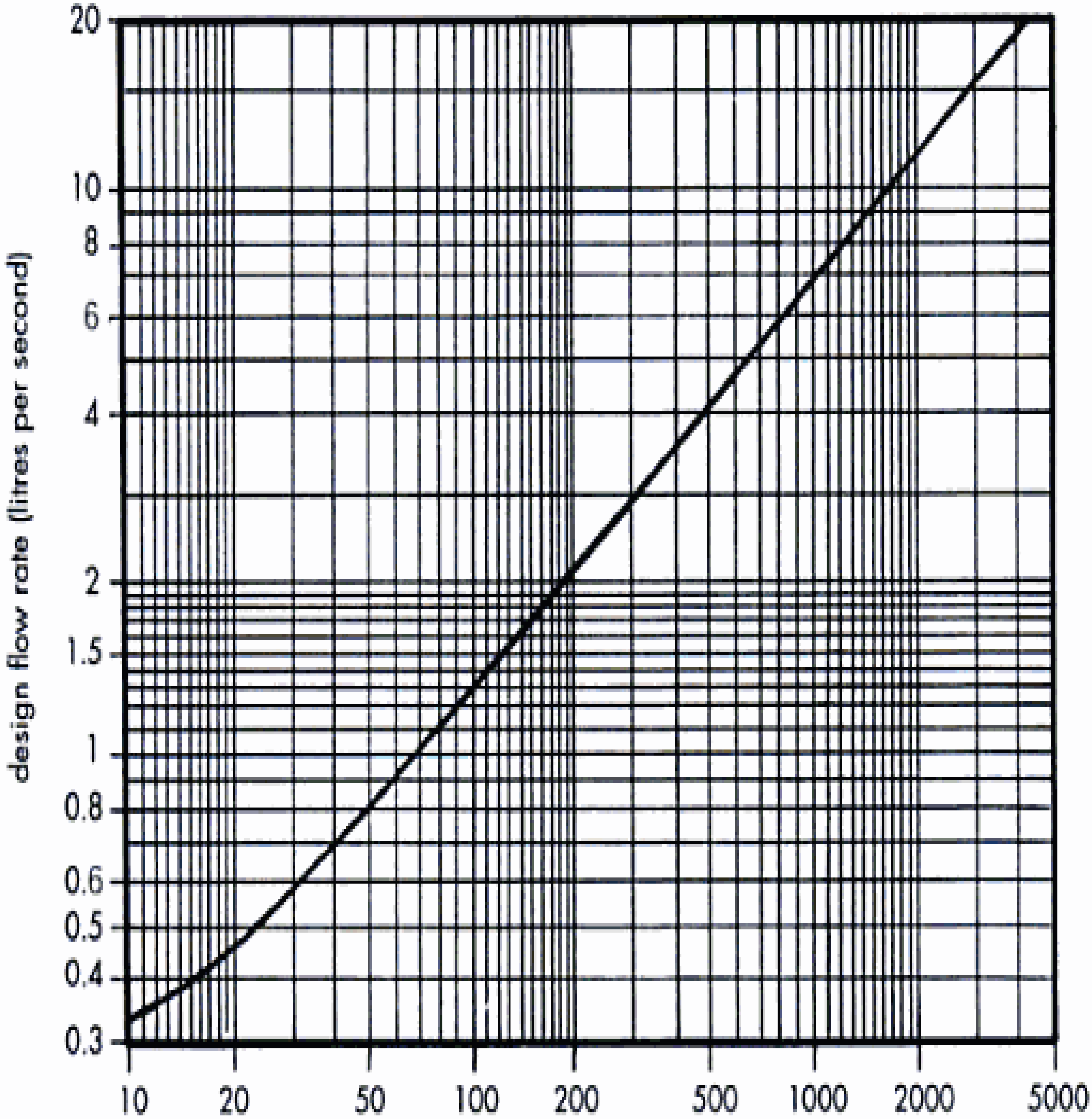
To minimise risk of Legionella infection: avoid release of water sprays, avoid water temperatures which may encourage the growth of Legionella and other micro-organisms, avoid water stagnation, don’t use materials which can harbour bacteria or provide nutrients for growth, maintain cleanliness throughout the systems, use water treatment techniques and ensure correct and safe operation and maintenance of the waste system and plant.

COLD AND HOT WATER PIPE SIZING

Below given table is to achieve loading units of appliances.

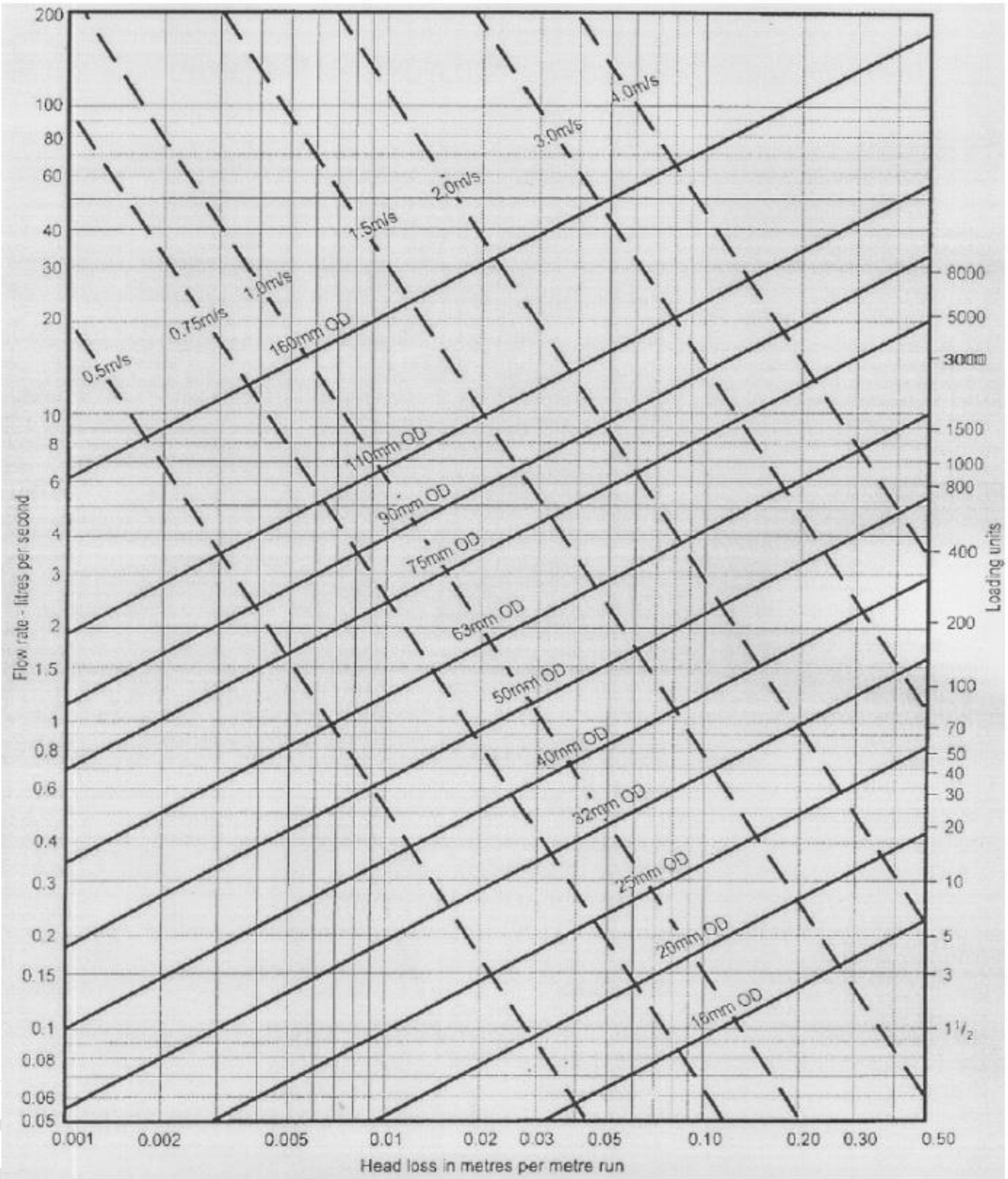
S.NO	DWELLINGS AND FLATS	LOADING UNITS
1	WC FLUSHING CISTERN(TANK)	2
2	WASH BASIN	1 ½
3	BATH	10
4	SINK	5
5	SHOWER(WITH NOZZLE)	3
6	PUBLIC BATH	22
	OFFICES	
1	WC FLUSHING CISTERN	2
2	WASH BASIN	3
	SCHOOLS AND INDUSTRIAL BUILDINGS	
1	WC FLUSHING CISTERN	2
2	WASH BASIN	3
3	LAB SINK	1

For calculating the flow rate of water litre per second refer to the chart given on next page.



Loading unit

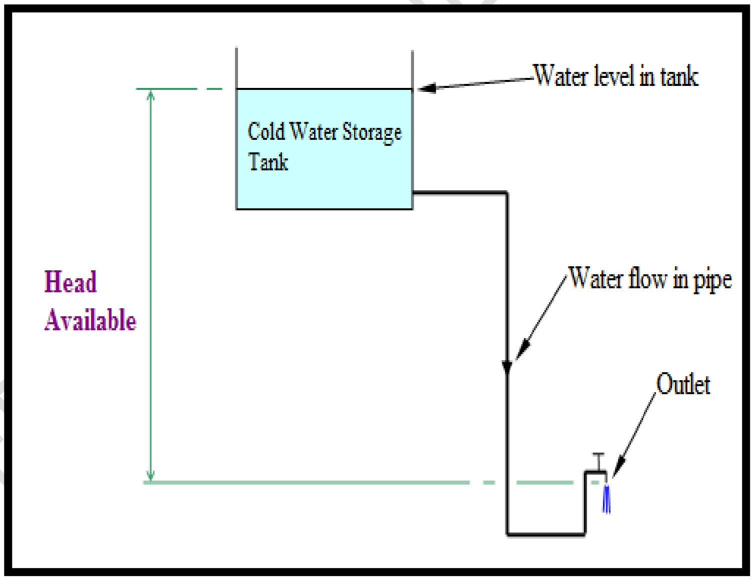
The chart given below is to select pipe sizing.



NON-PRESSURISED COLD WATER PIPE SIZING

The method is similar to L.T.H.W. pipe sizing except that the pressure available is not from a pump but from the head available from the tank.
The higher the tank is above the outlets the more head will be available to force the water through the outlets and overcome pipe work resistances.

HEAD AVAILABLE



The Head Available develops water pressure and this water pressure is used up in overcoming the frictional resistance of the pipe and in creating the velocity pressure for water flow at the outlet.

$p_1 - p_2$ = frictional resistance + velocity pressure

Or,

$h_1 - h_2$ = head loss in pipe due to friction + velocity head

Where **p =** **pressure (N/m^2)**
h = **head (m)**

In practice, to avoid additional velocity pressure calculations, it is usual to calculate the available pressure by considering the difference in levels between the bottom of the storage tank and the height of the draw-off points.

The pressure losses in the system are frictional pipe losses and velocity pressure loss through sanitary fittings such as taps, cistern ball valves and shower heads.

Velocity head loss through fittings is as follows:-

Pillar taps	1m
Shower head	1.5m
Ball valve	1m

WATER FLOW RATES

Cold water flow rates for sanitary appliances for small installations may be found from the table below.

In larger more complex buildings where many sanitary appliances are installed simultaneous demand should be considered from tables Guide B (1986) B4.20 and B4.21

Approximate hot or cold water demand	Flow rate (l/s)
Basin (spray tap)	0.05
Basin (tap)	0.15
Bath (private)	0.30
Bath (public)	0.60
Flushing cistern	0.10
Shower (nozzle)	0.15
Shower (100mm rose)	0.40
Sink (15mm tap)	0.20
Sink (20mm tap)	0.30
Wash fountain	0.40

Pipe Size Procedure

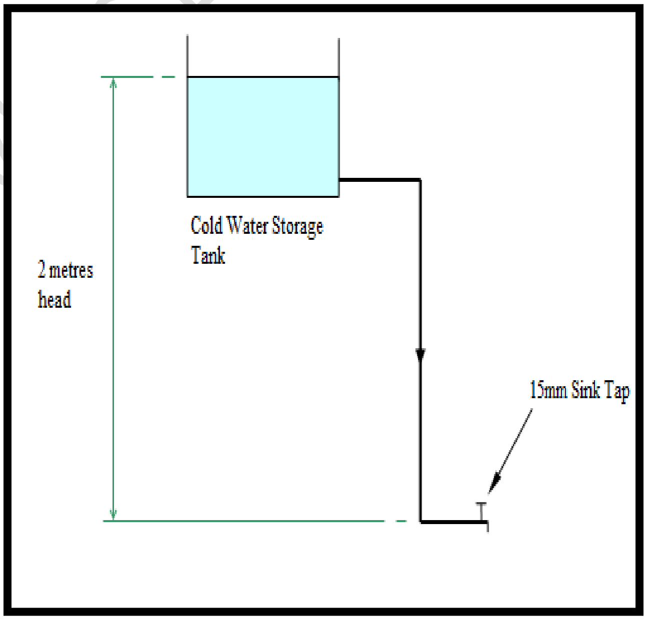
1. Divide system into sections.
2. Calculate demand units if simultaneous demand is effective.
3. Estimate flow rates in each section.
4. Estimate pipe diameter.
5. Measure the pipe run for the section.
6. Calculate length of pipe equal to resistance of fittings.
7. Calculate effective pipe length.
8. Determine pressure loss due to friction for pipe
9. Calculate pressure consumed by friction.
10. Calculate cumulative pressure consumed.

EXAMPLE 1

Determine a suitable pipe size for the system shown below.

DATA

Fittings include the following; exit from tank or large vessel, 3No. Bends, 1No. Gate valve, 1No. 15mm tap,
Length of pipe run is 8 metres and copper pipe is to be used.
The flow rate for a 15mm Sink Tap from above Table is 0.2 l/s.



The pressure available to force the water through the pipe work and tap comes from the head of water above the tap. The formula below gives the relationship between pressure and head.

$$P = \rho \times g \times h$$

Where;

P = pressure (N/m^2)
r = density (1000 kg/m^3 for water)
g = acceleration due to gravity (9.81 m/s^2)
h = head (m)

Therefore: $P = 1000 \times 9.81 \times 2.0 = 19{,}620\ N/m^2$

The resistance to flow is from the fittings and pipe work.

EXAMPLE 2

Determine suitable pipe sizes for the system shown below.
The building is a three-storey Nursing Home.

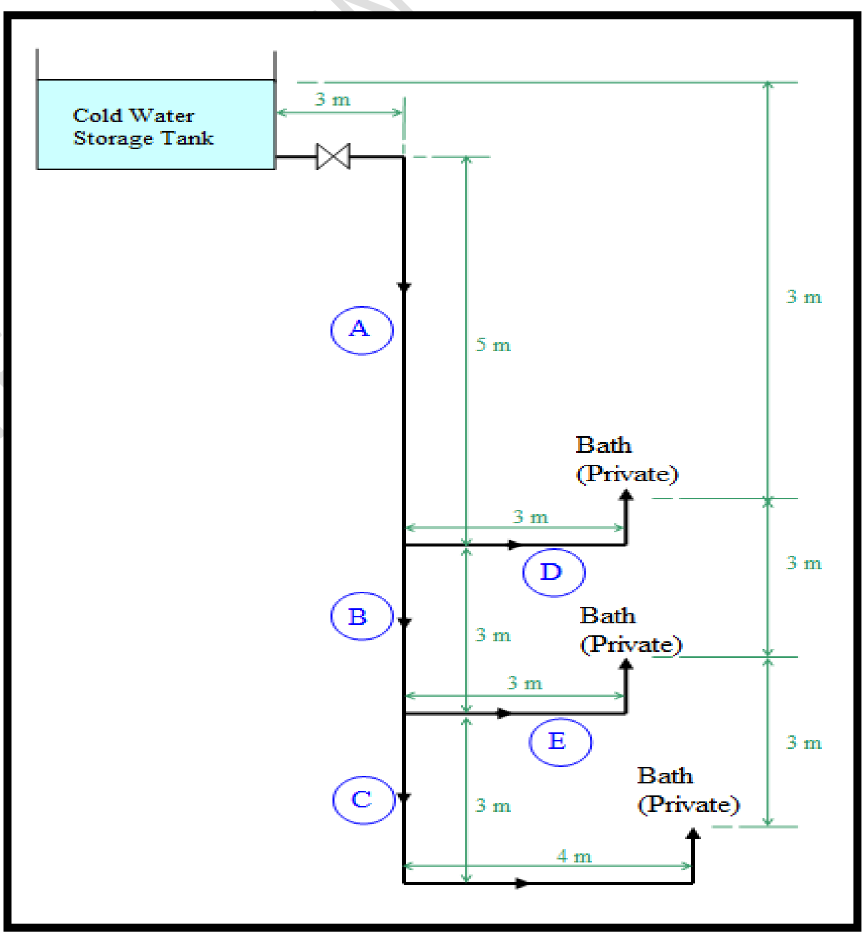
DATA

Copper pipe is to be used.
Flow rates are to be obtained from above Table.

ANSWER:

From above Table the flow rate for a private bath is 0.3 l/s.

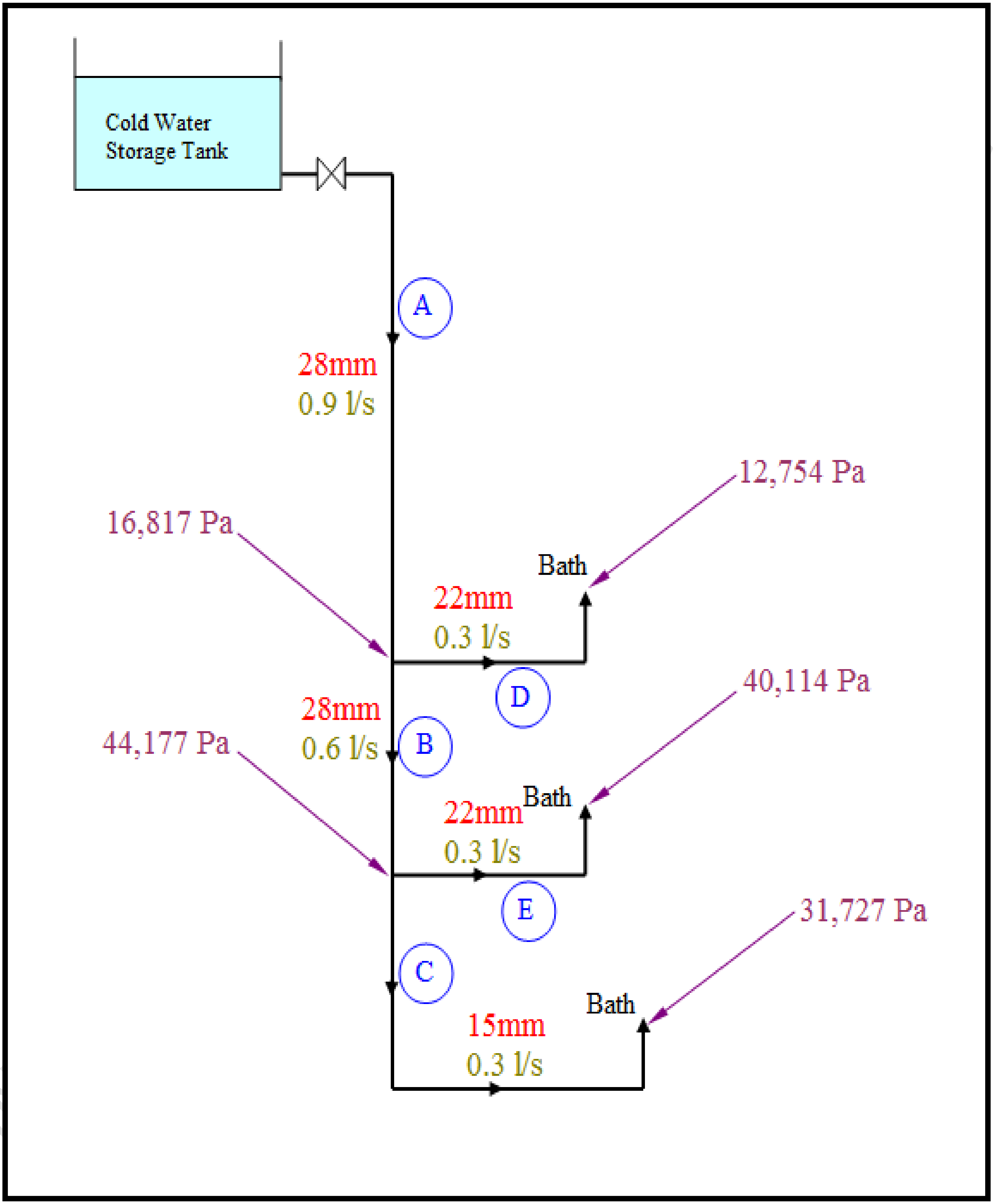
The pipe sizes, flow rates and pressures are indicated on the drawing below.



HOT AND COLD WATER PIPE SIZING TABLE

1	2	3	4	5	6	7	8	9	10	11	12
Ref	Demand Units if required	Flow Rate (l/s)	Estimated Pipe Dia. (mm)	Measured Pipe Run (m)	Length of Pipe Equal to Resistance's (m)	Effective Pipe Length Col. 5 + 6 (m)	Pipe Pressure Loss (Pa/m)	Pressure Consumed Col. 7 x 8 (Pa)	Total Pressure Consumed (Pa)	Pressure Available at End of Section (Pa)	Final Pipe Size (mm)
A		0.9	28	8.0	ζ Factors for fittings: 1No.Exit large vessel = 0.4 1No.Gate Valve = 0.3 1 No. Bend = 1.0 1 No.28 x 28 x 22 tee = 0.2 ----------- Total 1.9 T.E.L. = Total ζ x le = 1.9 x 1.1 = 2.09 m	8 + 2.09 = 10.09 m	1250	12,613	12,613	Static pressure = 3m x 9810 = 29,430 Press. Available = 29,430 – 12,613 = **16,817 Pa**	28
B		0.6	28	3.0	1No.28 x 22 x 22 tee ζ = 0.20 with 28 x 22 reducer: $A_2 / A_1 = \pi \times 0.011^2 / \pi \times 0.014^2$. = 0.617 gives ζ = 0.25 ----------- Total 0.45 T.E.L. = Total ζ x le = 0.45 x 1.0 = 0.45m	3.0 + 0.45 = 3.45 m	600	2,070	12,613 + 2,070 = 14,683	Static pressure = 6m x 9810 = 58,860 Press. Available = 58,860 – 14,683 = **44,177 Pa**	28
C		0.3	22	7.0	1No.Bend = 1.0 1No. Angle valve bath tap = 5.0 ----------- Total 6.0 T.E.L. = Total ζ x le = 6.0 x 0.7 = 4.2 m	7.0 + 4.2 = 11.2 m	625	7,000	14,683 + 7,000 = 21,683	Static pressure = 9 m x 9810 = 88,290 Press. Available = 88,290 – 21,683 = **66,607 Pa**	22

D		0.3	22	3.0	1No. Angle valve bath tap = 5.0 T.E.L. = Total ζ x le = 5.0 x 0.7 = 3.5 m	3.0 + 3.5 = 6.5 m	625	4,063	12,613 + 4,063 = 16,676	Static pressure = 3m x 9810 = 29,430 Press. Available = 29,430 – 16,676 = **12,754 Pa**	22
E		0.3	22	3.0	1No. Angle valve bath tap = 5.0 T.E.L. = Total ζ x le = 5.0 x 0.7 = 3.5 m	3.0 + 3.5 = 6.5 m	625	4,063	4,063	Static pressure = 6m x 9810 = 58,860 Press. Available = 58,860 – 14,683 = 44,177 Pa – 4,063 = **40,114 Pa**	22
Re-calculate pipe ref. C for 15mm pipe											
C		0.3	15	7.0	1No. 28 x 15 x 22 tee (already included) with 2 No.28 x 15 reducers: $A_2 / A_1 = \pi \times 0.0075^2 / \pi \times 0.014^2$. = 0.287 gives ζ = 0.47 2No. Reducers = 0.94 1No.Bend = 1.0 1No. Angle valve bath tap = 5.0 ----------- Total 6.94 T.E.L. = Total ζ x le = 6.94 x 0.5 = 3.47 m	7.0 + 3.47 = 10.47 m	4000 estimated	41,880	41,880 + 14,683 = 56,563	Static pressure = 9 m x 9810 = 88,290 Press. Available = 88,290 – 56,563 = **31,727 Pa**	15

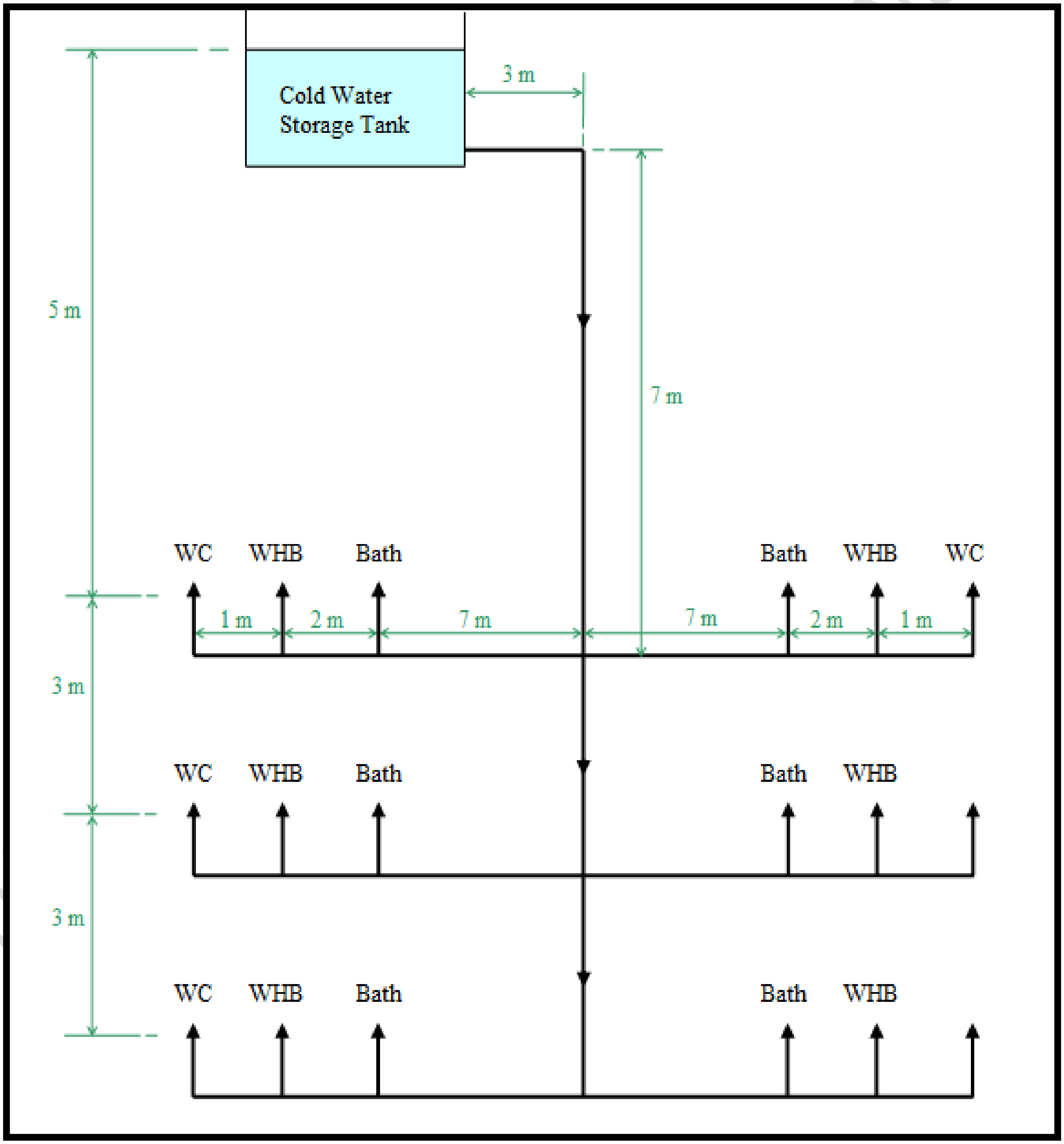

Cold Water
Storage Tank
A
28mm
0.9 l/s
12,754 Pa
16,817 Pa
Bath
22mm
0.3 l/s
D
40,114 Pa
28mm
0.6 l/s
B
44,177 Pa
Bath
22mm
0.3 l/s
E
31,727 Pa
C
Bath
15mm
0.3 l/s

EXAMPLE 3

Determine suitable pipe sizes for the system shown below.
The building is a three-storey hotel.

DATA

Copper pipe is to be used.
Flow rates and simultaneous demand data are to be obtained from the guide.



Hot and Cold Water Pipe Sizing Table

1	2	3	4	5	6	7	8	9	10	11	12
Ref	Demand Units if required	Flow Rate (l/s)	Estimated Pipe Dia. (mm)	Measured Pipe Run (m)	Length of Pipe Equal to Resistance's (m)	Effective Pipe Length Col. 5 + 6 (m)	Pipe Pressure Loss (Pa/m)	Pressure Consumed Col. 7 x 8 (Pa)	Total Pressure Consumed (Pa)	Pressure Available at End of Section (Pa)	Final Pipe Size (mm)

MAINS WATER PIPE SIZING

PIPE SIZING PROCEDURE

1. Reference the pipe section.

2. Calculate flow rates from Table below.

3. Estimate flow rates in each section.

4. Estimate pipe diameter from pipe sizing tables.

5. Measure the pipe run from drawings.

6. Calculate length of pipe equal to resistance of fittings.
The Total equivalent length of a fitting = Equivalent Length x Pressure Loss factor z (Zeta).

7. Calculate effective pipe length.

8. Determine pressure loss due to friction from Tables.

9. Calculate pressure consumed due to friction (Pa) = effective pipe length (m) x pressure loss due to friction (Pa/m)

10. Calculate total pressure consumed = Friction loss + Static pressure loss

11. Determine pressure at start of section.

12. Calculate pressure available at end of section = Pressure at start of section - Total pressure consumed
If pressure available at end of section is less than the maximum allowable pressure drop then we can accept this pipe size.

13. Determine pressure required at end of section, this can be the minimum pressure that is required for terminal equipment.

14. If the pressure available at the end of the section is more than or equal to the pressure required at the end of the section then the pipe size is correct.

WATER FLOW RATES

Cold water flow rates for sanitary appliances for small installations may be found from the table below.

In larger more complex buildings where many sanitary appliances are installed simultaneous demand should be considered from tables Guide B (1986) B4.20 and B4.21.

Approximate hot or cold water demand	Flow rate (l/s)
Basin (spray tap)	0.05
Basin (tap)	0.15
Bath (private)	0.30
Bath (public)	0.60
Flushing cistern	0.10
Shower (nozzle)	0.15
Shower (100mm rose)	0.40
Sink (15mm tap)	0.20
Sink (20mm tap)	0.30
Wash fountain	0.40

Pressurised Cold Water Pipe Sizing Table													
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ref	Demand Units if required	Flow Rate (l/s)	Estimated Pipe Dia. (mm)	Measured Pipe Run (m)	Length of Pipe Equal to Fittings Resistance's (m)	Effective Pipe Length Col. 5 + 6 (m)	Pipe Pressure Loss (Pa/m) From CIBSE Tables	Pressure Consumed due to Friction Col. 7 x 8 (Pa)	Friction loss + Static pressure loss = Total Pressure Consumed (Pa)	Pressure at Start of Section (Pa)	Pressure Available at End of Section (Pa)	Pressure Required at End of Section (Pa)	Final Pipe Size (mm)

CALCULATION OF TRANSFER PUMP

There are two items required to size a pump;

- FLUID FLOW RATE
- PRESSURE TO BE DEVELOPED

FLUID FLOW RATE

Calculate capacity of over head water tank. For example size of the tank is Leanth-5meters, width 3meters and height is 3meters.

Cubic meter = l x w x h

Take out the air gap maintenance space 30cm from height.

CM = 5 X 3 X 2.7

CM = 40.5

Hence 1 cubic meter = 1000leters

40500 litres

The requirement of the water filling in over tank is 1hour.

1hour = 60 minuets

1 minuets =60 seconds

F = litres / minuets

F = 40500 / 60 F = 675

F = litres / seconds

F = 675 / 60

F = 11.25 l/s

As above calculation we have achieved 11.25 l/s is the flow rate.

NOTE: For converting litres in to imp. Gallon litres divided by 4.5.
For converting litres in to us. Gallon litres divided by 3.78.

PRESSURE TO BE DEVELOPED

The pressure that should be developed by the pump should equal the Pressure Drop in the system.

This is usually found from pipe sizing tables. The flow rate of fluid is also found from pipe sizing tables or given in other data.

Add 20% margin to pump pressure to allow for future extensions and the system getting less efficient.

The designer must be careful when adding a margin to pump pressure since too much pressure can lead to 'pumping over' in open systems and other problems.

Some pump catalogues have units of head instead of pressure.

HYDRAULIC CALCULATION FOR TRANSFER PUMP

Total Domestic Storage Tank _______ gallons based on __ hours filling time

The required flow rate is ____ gpm through a ___ inch dia. (____ mm dia.) Pipe at a frictional loss of ____ /1m of straight pipe run.

1 **Head lost through linear pipe length**

Total length of piping	=	____**m**
	=	____m x ____ / 1m
	=	____m

2 **Head lost through elbows**

Total nos. of elbows	=	____ nos.
Each elbow is equivalent to	=	____m of straight pipe run
Therefore, Head lost through elbows	=	____ x____m
	=	____m

3 **Head lost through tees**

Total nos. of tees	=	____ nos.
Each tee is equivalent to	=	____m of straight pipe run
Therefore, Head lost through tees	=	____ x____m
	=	____m

4 **Head lost through valves**

Total nos. of valves	=	____ nos.
Each valve is equivalent to	=	____m of straight pipe run
Therefore, Head lost through valve	=	____ x____m
	=	____m

5 **Static head required** = ____m

The difference in height between the pump level in the suction tank on the ground level and the highest storage tank.

6 **Total head required by pump**

Head lost through linear pipe length	=	____m
Head lost through elbows	=	____m
Head lost through tees	=	____m
Head lost through valves	=	____m
Static head required	=	____m
Total head required	=	____m

7 Selected Duty & Standby Pump Capacity

Flow rate capacity	=	____ gpm @ ____ L/s
Head	=	____ bar @ ____ m

NOTE: Friction losses of fittings are as given on next page.

Friction loss through linear pipe length can get from above mention pipe sizing table.

Static head can be achieved from the height of the building.

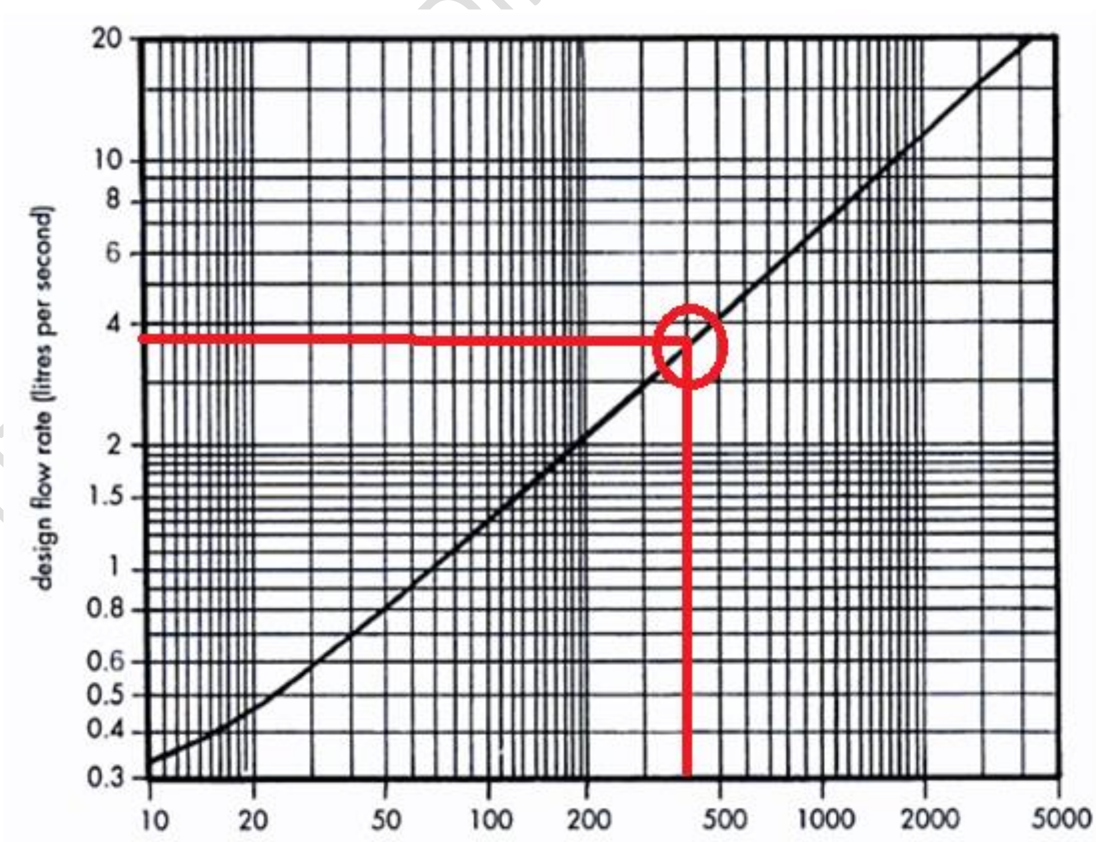
Approximate friction loss for uPVC and CPVC fittings in Equivalent Length in meters of Straight Pipe for water can be found in the table below:

Friction Loss Equivalent Length – meter of Straight Pipe													
Fitting	Nominal Pipe Size												
	15mm	20mm	25mm	32mm	40mm	50mm	63mm	90mm	100mm	150mm	200mm	250mm	300mm
90º Elbow, long sweep radius	0.457	0.609	0.762	1.158	1.219	1.737	2.103	2.407	3.657	5.486	6.705	7.924	9.753
90º Elbow, standard sharp inside radius	1.097	1.371	1.615	2.042	2.286	2.621		3.383	3.992				
45º Elbow	0.243	0.335	0.426	0.548	0.640	0.792	0.944	1.219	1.554	2.438	3.230	4.114	4.72
valves	0.10	0.121	0.182	0.243	.3048	0.457	0.609	0.914					
Tee Flow - Run	0.3048	0.426	0.518	0.701	0.822	1.310	1.554	1.889	2.529	3.81	5.029	5.334	6.096
Tee Flow - Branch	1.219	1.524	1.828	2.133	2.438	3.657	4.572	4.876	6.705	9.966	14.935	17.373	20.421
Male/Female Adapter	0.3048	0.457	0.609	0.853	1.066	1.371	1.676	1.981	2.743	4.267			

CALCULATION OF BOOSTER PUMP

FLOW RATE: calculate flow rate by useing loading unit table and flow rate graph given below.

S.NO	DWELLINGS AND FLATS	LOADING UNITS
1	WC FLUSHING CISTERN(TANK)	2
2	WASH BASIN	1 ½
3	BATH	10
4	SINK	5
5	SHOWER(WITH NOZZLE)	3
6	PUBLIC BATH	22
	OFFICES	
1	WC FLUSHING CISTERN	2
2	WASH BASIN	3
	SCHOOLS AND INDUSTRIAL BUILDINGS	
1	WC FLUSHING CISTERN	2
2	WASH BASIN	3
3	LAB SINK	1



EXAMPLE

In a multi story building, three floor to be served with boosted water in which the total appliances will be.

WATER CLOSET ----- 24 NOS

WASH BASIN ---------- 30 NOS

BATH TUB -------------- 24 NOS

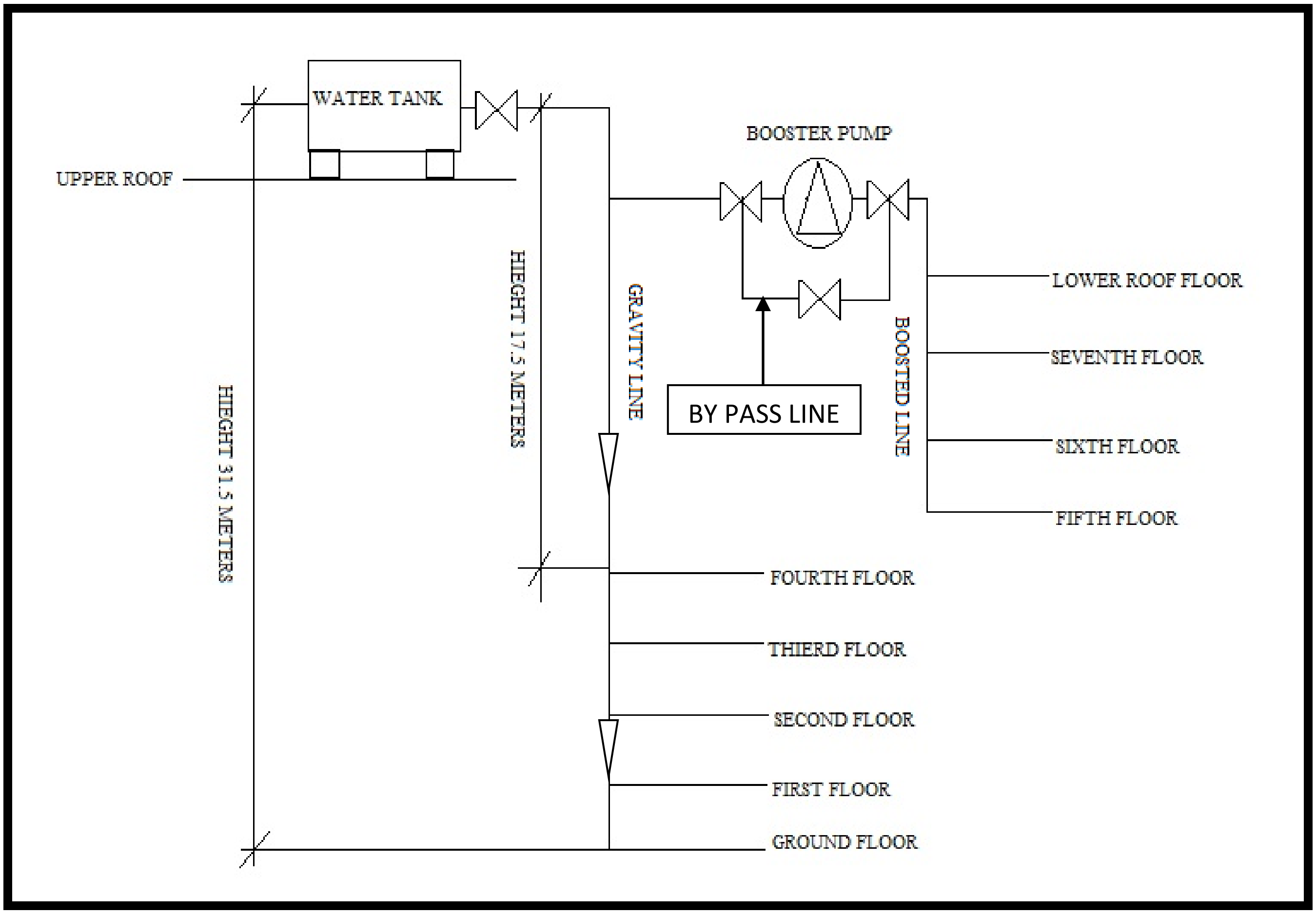
KITCHEN SINK -------- 10 NOS

By using above mention graph and table

s.no	appliances	Nos.	Loading unit	Total loading units
1	Water closet	24	2	48
2	Wash basin	30	1 1/2	45
3	Bath tub	24	10	240
4	Kitchen sink	10	5	50
				383 SAY 400

From the above graph the required flow rate is 3.9 litre/seconds.

PRESSURE: for booster pump is little bit differ from transfer pump below diagram is an example.



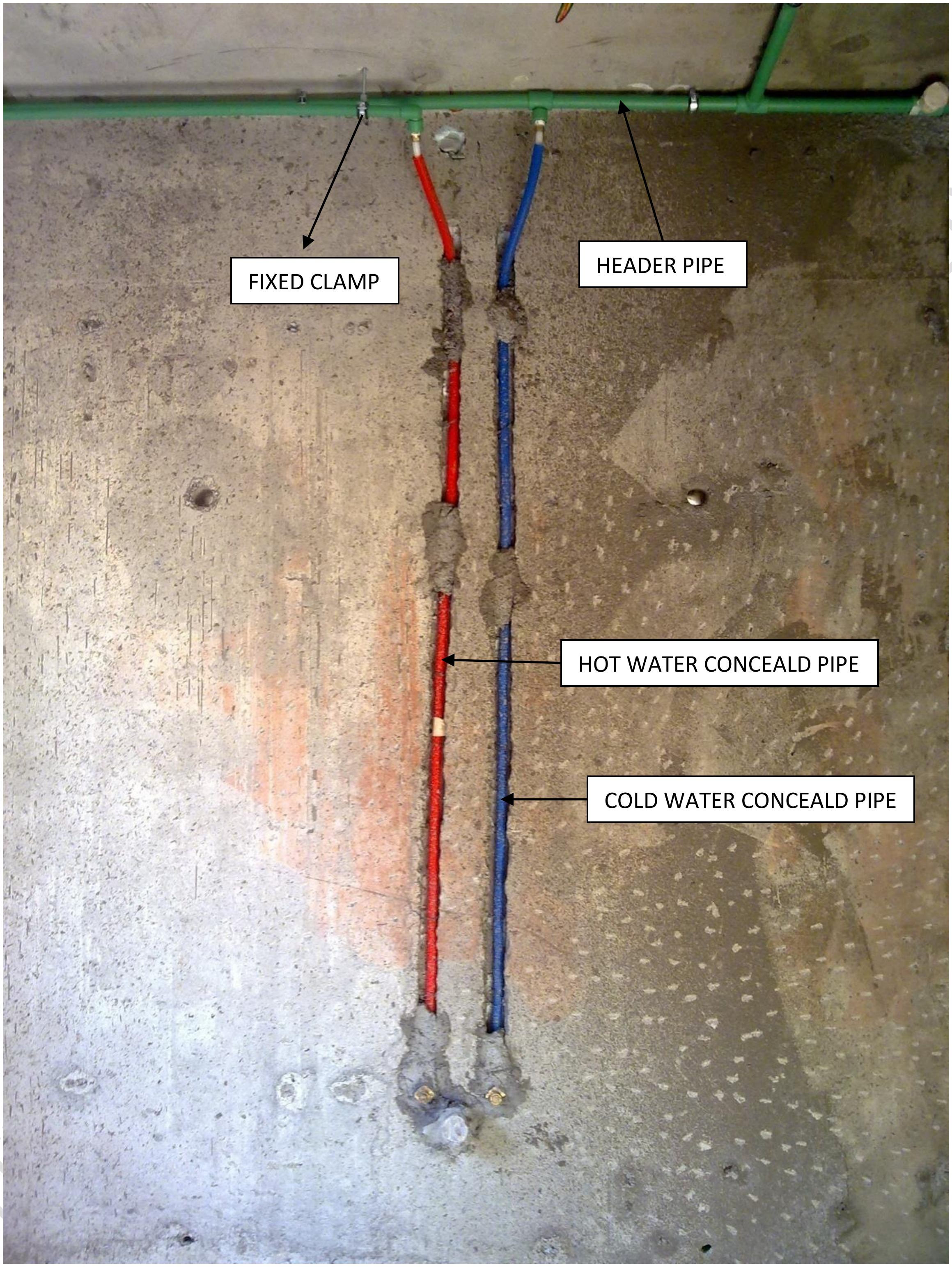
From above diagram the total height of the building is 31.5 meters including tank level. As it has been observe 1 bar = 10.2 meters, according to this the total end pressure of the system is 31.5 divided by 10.2.

Hence answer will be 3.08 bars at the end of the pipe which is at ground level. And at fourth floor it will be 1.71 bars.

NOTE: the satisfactory pressure at the using of appliances is 1.5 bars is the minimum satisfactory pressure.

As we have noticed the minimum satisfactory pressure is 1.5 bars. And at fourth floor it is reaching till 1.71 bars it means from fourth floor till ground floor can be provided by gravity line for satisfactory pressure. But from lower roof to fifth floor there will be no pressure of satisfaction. To get the satisfactory pressure, use booster pumps to boost the water to its satisfactory level.

For calculating head of booster pump use formulas same as transfer pump except static head because in booster pump on roof will have positive static head.



TYPICAL A INSTALLATION FOR CONCEALD PIPING AND CONNECTIONS

A TYPICAL INSTALLATION OF MAIN PIPES COMING FROM METER ROOM