3.3.9 Maintenance

Softened water is not usually required for toilet cisterns, gardens or over the yard disconnector gully; a separate hard-water supply should be provided for these purposes.

Maintenance and care of water softeners is simple. It includes the following points:

- Regular backflushing and regeneration.
- Preservation of the outer protective coating by washing off all traces of salt after regeneration and the use of proper spanners to remove and replace the salt cap.
- Removal of any serious water hammer to relieve undue strain on the cylinder, piping and valves.
- Replacement of the softening medium as necessary.
- Instructions of the manufacturer to be observed at all times.

NOTES

4 STERILISATION OF WATER

4.1 PRESENCE OF CONTAMINANTS

Contaminants, which cause water pollution, are organic materials which may be in the form of suspended animal or vegetable matter, animal excreta, bacteria and microscopic organisms.

These contaminants can cause communicable diseases such as dysentery, infectious hepatitis, typhoid and cholera.

4.1.1 Reduction of organic matter

All organic matter can be oxidised to stable mineral substances, e.g. carbon compounds to carbon dioxide and nitrogenous matter, ammonia to nitrates and sulphur-bearing compounds to sulphates.

This reduction of organic matter is a continual natural process aided by the action of certain classes of bacteria (anaerobes) which act as catalysts in the process. This process is slow, but may be hastened by supplying an excess of oxygen to the water, either by spraying the water into the air, or by charging the water with compressed air.

Where large quantities of water are handled daily for community purposes, the natural purification processes are too slow. Purification by filtration, followed by chemical sterilisation, or by chemical sterilisation alone, is adopted. The chemicals used supply the oxygen at a rapid rate and so hasten the purification process.

4.1.2 Requirements of chemical sterilisation

Chemical sterilisation of water must satisfy the following:

- The water must be palatable and not harmful or unpleasant.
- It should not cause any precipitate because of its cost of removal.
- The agent must be simple and economical to apply.
- The plant for its application must permit sensitive and accurate control and be trouble-free in operation over a long period.
- The initial cost of the plant should be in proportion to the volume of water treated.

Sterilisation involves the destruction of all pathogenic bacteria and should not be confused with the use of antiseptics which render them harmless by preventing their development.

Although filtration should hold back most of the organisms, all drinking water should be sterilised, whether filtered or not, unless it is known to be from a safe source.

4.1.3 Sterilisation of water by chlorine

Chlorine is recognised as the most effective bactericide and is the chemical agent most used in the sterilisation of water. It is germicidal in very small concentrations and its action is quick and reliable.

Unfortunately, chlorine has less affinity for organisms than for other forms of organic matter. Therefore, sufficient of this chemical must be added to the water to oxidise the organic matter and other impurities and leave a balance of free chlorine to kill the germs.

Chemical action of chlorine

Chlorine, when in solution with water, forms hypochlorous acid, which decomposes to hydrochloric acid and oxygen. It is this oxygen plus the toxic content of the chlorine that are available to oxidise the organic matter and destroy the bacteria.

The chlorine must remain in contact with the organisms for at least 20 minutes in order to destroy them.

Effect of chlorine in water

When a dose of chlorine is added to natural water, a proportion of the chlorine is dissipated or deviated immediately due to the presence of oxidisable organic matter. The amount of chlorine remaining after this initial deviation is referred to as 'residual chlorine'. In simple chlorination, this residual chlorine is not persistent and disappears in a short time owing to continued deviation.

Overchlorination can cause a bad taste in the water due to dead micro-organisms, etc. Amelioration of overchlorination can be achieved by filling receptacles with the water and allowing the excess chlorine to evaporate over a period.

Factors influencing deviation of chlorine

The rate of deviation of chlorine in water depends on:

- The amount of oxidisable organic matter in the water.
- The temperature of the water.
- Exposure to light.

Deviation of the chlorine will continue until the chlorine demand of the water has been satisfied.

Residual chlorine

Because of the slower action in killing bacteria and other harmful micro-organisms, it is essential that residual (free) chlorine be present in the water after the organic matter has been oxidised.

Chlorine should be added to the water in small amounts until a point is reached when the addition of further chlorine will produce a proportional increase in the residual chlorine. This is referred to as 'break point'. At this point, the chlorine demand of the water is fully satisfied, i.e. sufficient chlorine has been added to chlorinate all matter that will react.

Sources of chlorine for water sterilisation

Chlorine may be added to water in one of several forms. Sources from which this chemical may be obtained are:

- Gaseous chlorine
- Water-sterilising powder
- Sodium hypochlorite

Gaseous chlorine

This is used for large permanent water supplies. The gas is obtained from cylinders of liquid chlorine under pressure and fed through a pressure-reducing valve to a regulating apparatus (Chloronome or Chloroscope) where it is mixed with the required amount of water and is then fed to the main supply at the desired rate.

WARNING:

Chlorine in solution is very corrosive and all apparatus in contact with the solution is constructed of cast brass, glass, polypropylene or rubber.

It is explosive.

Inhalation in large quantities will cause death.

Water-sterilising powder (Bleaching powder)

This powder consists of a mixture of calcium oxychloride, calcium hydrate and a little moisture. When freshly prepared it should have an available chlorine content of 33 per cent approximately. Unfortunately, it is very unstable, its chlorine being readily set free by the action of moisture, CO_2, heat and light.

The bleaching powder is first mixed with water in a bucket and allowed to stand. When the slaked lime settles it leaves a clear chloride solution on top. This solution is added to the water to be treated and thoroughly mixed.

This method of sterilisation is used for small quantities of water, e.g. country swimming pools.

Filtration prior to sterilisation

When applying chlorine to water, it must be borne in mind that all organic matter must be oxidised and germs killed to effect complete sterilisation. If large quantities of suspended organic matter are present in the water, the available oxygen will be suspended on this matter, thus preventing thorough sterilisation unless larger quantities of chlorine are used.

The chlorine cannot penetrate large particles of infective material. Therefore, some form of filtration or precipitation should precede sterilisation in these cases.

Determination of free chlorine

Two methods may be used to determine if residual chlorine is present in water. These are:

- Cadmium, iodide and starch indicator.
- Orthotolidine indicator.

Cadmium, iodide and starch indicator

A small quantity of treated water (0.3 litres) is drawn from the supply and three drops of indicator are stirred into it. A faint blue colour indicates the presence of free chlorine. Greater residual will give deeper shades of blue.

Orthotolidine indicator

To 100 c.c. of treated water add 1 c.c. of orthotolidine solution. A yellow colour indicates free chlorine. By comparison with standard colour plates, a close approximation of the quantity of free chlorine can be determined.

If a green colour instead of yellow is formed, the mixture is too alkaline and more indicator agent must be added.

4.1.4 Methods of dechlorinating water

Free chlorine in strengths up to 0.5 P.P.M. (parts per million) in water which has been efficiently sterilised is imperceptible to most palates; in strengths exceeding this figure it becomes noticeable.

The following chemicals may be used to remove excess chlorine from water after the necessary contact period has elapsed:

- Sulphur dioxide
- Activated charcoal
- Sodium thiosulphate

Sulphur dioxide

Sulphur dioxide gas is fed into the water through the same type of apparatus used for administering chlorine.

Activated charcoal

Contact with activated charcoal not only removes chlorine but also colour, odours and tastes from water.

Sodium thiosulphate

This chemical is useful for dechlorinating small quantities of water. Half a gram of sodium thiosulphate dissolved in water will remove 1 P.P.M. of chlorine from 450 litres of water.

4.1.5 Other methods of sterilising water

Although chlorination, owing to cheapness and good results, is regarded as the most satisfactory method of sterilising water, other methods can be adopted depending upon circumstances. Some of these methods are:

- Boiling
- Distillation
- Acid sodium sulphate
- Catadyn silver
- Ultra-violet rays

Boiling

This method is only practicable for domestic requirements. Boiling water for 10 minutes kills all disease-producing pathogenic bacteria and should be used as a precautionary measure in cases of water-borne epidemics, e.g. typhoid fever.

Distillation

This method involves converting the water to steam, then condensing the steam back to water. It produces an absolutely pure water which is flat and tasteless. If required for drinking purposes it should be aerated so that oxygen and CO_2 can be absorbed to revive the taste.

Acid sodium sulphate

For drinking supplies, tablets of one gram are added to one pint (0.6 litre) of water, but a long contact period is required.

Catadyn silver

This is a more recent development in water treatment and is suitable for swimming pool sterilisation.

It is an active form of silver which is obtained by electrolytic decomposition of a silver anode. The methods used in this type of sterilisation are:

- The silver is deposited on a sand filter bed where it sterilises the water in from 2 to 12 hours. The action continues after filtration so that the water need not be in contact with the filter for any prolonged period.
- A small quantity of water passes between the anode and cathode, thereby acting as an electrolyte. The silver is carried away by the water and is thereby charged with silver ions. This mixture of water and silver ions is then fed to the main supply thus activating and sterilising it as a result.

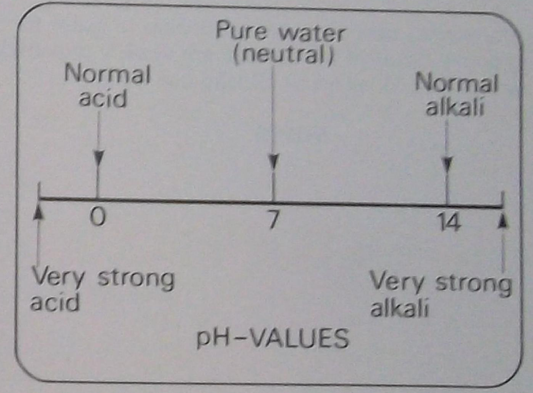
Ultra-violet rays

Ultra-violet rays play an important part in the natural sterilisation of water and act near its surface. Therefore, shallow water under the effects of bright sunlight will be reasonably sterile, depending on the time of exposure to the rays. Hence the reason for drawing water from a reservoir near its surface.

4.1.6 pH Value of water

The acidity or alkalinity of a solution is conveniently expressed as its pH value which is defined as the negative logarithm of the hydrogen ion concentration, i.e. $pH = -\text{Log}(H^+)$.

Pure water has a pH value of 7, a 'normal acid solution' 0, and a 'normal alkaline solution' is 14. In diagram form, this may be shown as follows:



When water is chlorinated, small amounts of acid are produced. Therefore, it is necessary at times to test the water for its pH value and so take appropriate action if the test indicates that excessive acid or alkaline conditions exist.

Should excessive acid conditions exist, soda ash (sodium carbonate) is added to the water to produce the desired pH value. When excessive alkaline conditions prevail, alum is added to obtain a neutral water.

Recognised pH standards of water

The standard pH range recognised by the World Health Organisation for potable water is as follows:

- Permissible — 7.0 to 8.5
- Excessive — Less than 6.5 or greater than 9.2

Experience has proved that the pH of water for swimming pools should be kept in the range 7.5 to 8.0 in order to maintain pleasant conditions for bathers and be effective for chlorination.

Testing for pH value

The pH value of water may be determined chemically or by using litmus paper.

Chemical test

The same comparator used for testing water for free chlorine can be used for measuring the pH of water. Phenol red indicator solution is placed in the required amount of water and thoroughly mixed. The mixed solution is then compared with coloured discs and the pH value determined.

Should the water to be tested contain residual chlorine, a small crystal of analytical-grade sodium thiosulphate should be added to the water sample to destroy the free chlorine before adding the indicator solution.

Litmus paper test

This is a simple test which involves immersing one end of a strip of litmus paper in a sample of the water to be tested. The colour of the litmus paper will change according to the degree of acidity or alkalinity of the water. The pH value is determined by comparing the colour of the litmus paper with an identifying colour chart.

The sterilising and testing procedures described are applicable to water for industries, human consumption and swimming pools. Detailed procedures are usually provided with the equipment and materials and should be carefully followed by all who use them.

NOTES

5 APPLIANCES FOR RAISING WATER

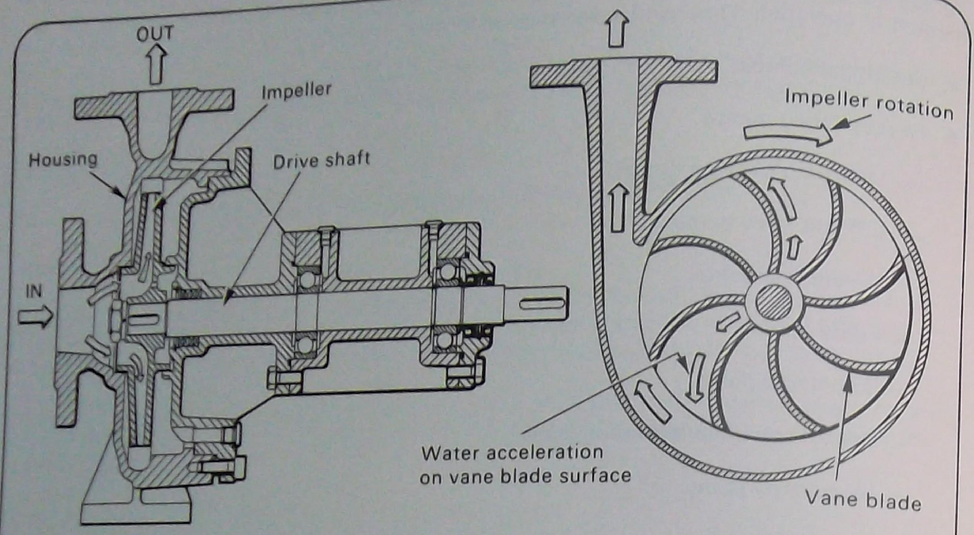
Many types of pumps are manufactured and the installation, maintenance and repair of many of them are often a matter for a specialist. However, as the tradesman most concerned with water supply, the plumber should have a good understanding of pumps used for raising water.

Pumps are generally referred to according to their principle of action, manner of construction, or method of operation. They can be classified as follows:

- Centifugal pumps.
- Reciprocating pumps.
  - — Lift pump (Suction pump).
  - — Lift and force pump.
  - — Differential pump.
  - — Force pump.
  - — Diaphragm pump.
  - — Double-acting reciprocating pump.
  - — Semi-rotary pump.
  - — Deep-well pump.
- Rotary pumps.
  - — Gear pump.
  - — Turbine pump.
  - — Mono pump.
  - — Vane pump.
- The hydraulic ram.
- Ejectors.
- Hydropneumatic pumping systems.

5.1 THE CENTRIFUGAL PUMP

This type of pump utilises the principle of centrifugal force for its operation. Owing to its flexibility, the centrifugal pump is widely used in water supply systems, particularly where automatic control is necessary or hot water is to be pumped.



CROSS-SECTION THROUGH PUMP & DRIVE

CROSS-SECTION THROUGH IMPELLER

CENTRIFUGAL PUMP

5.1.1 Construction

- Casing
  - Generally of cast iron or other cast metal or plastic and is of a volute shape gradually increasing in cross-section towards the delivery pipe.
- Impeller
  - Fitted with vanes or blades and may be of the closed type with the vanes mounted between two discs, semi-enclosed with a disc mounted on one side of the vanes, or it may be fully open (no discs). The open type is less efficient than the other two.
- Vanes
  - Have a backward curve to the direction of rotation to minimise frictional resistance offered to the water as it passes from the centre of the impeller along the blade to its tip by centrifugal force.

5.1.2 Operation

As the impeller is revolved at high speed, the water is flung by centrifugal force from the inlet 'eye' to the tip of the vanes and thence into the volute casing. As the water is flung into the enlarging passage of the casing, it tends to form a vacuum at the centre of the impeller where the inlet pipe enters the casing. The water flows through the inlet pipe and into the pump, either by gravity or by suction, where the pump is situated above the water to be pumped.

When it leaves the impeller blades, the water collects in the casing and is forced through the outlet at a constant pressure.

5.1.3 Efficiency

Because of its design and principle of operation, the centrifugal pump gives its best performance when used at the rate of discharge and head for which it is designed. The efficiency of the pump falls off when these conditions are varied.

For a given pump the delivery, head and power input will all increase as the speed increases. Thus, to make a pump deliver more water, or pump against a greater head, the speed must be increased. However, it is undesirable to drive simple pumps of this type at very high speeds; a larger capacity pump should be installed.

5.1.4 Installation

A centrifugal pump will not operate unless the casing is full of water.

Where a pump is installed, as in the following illustration (page 32), the casing is kept full by water flowing by gravity from the tank at the right.

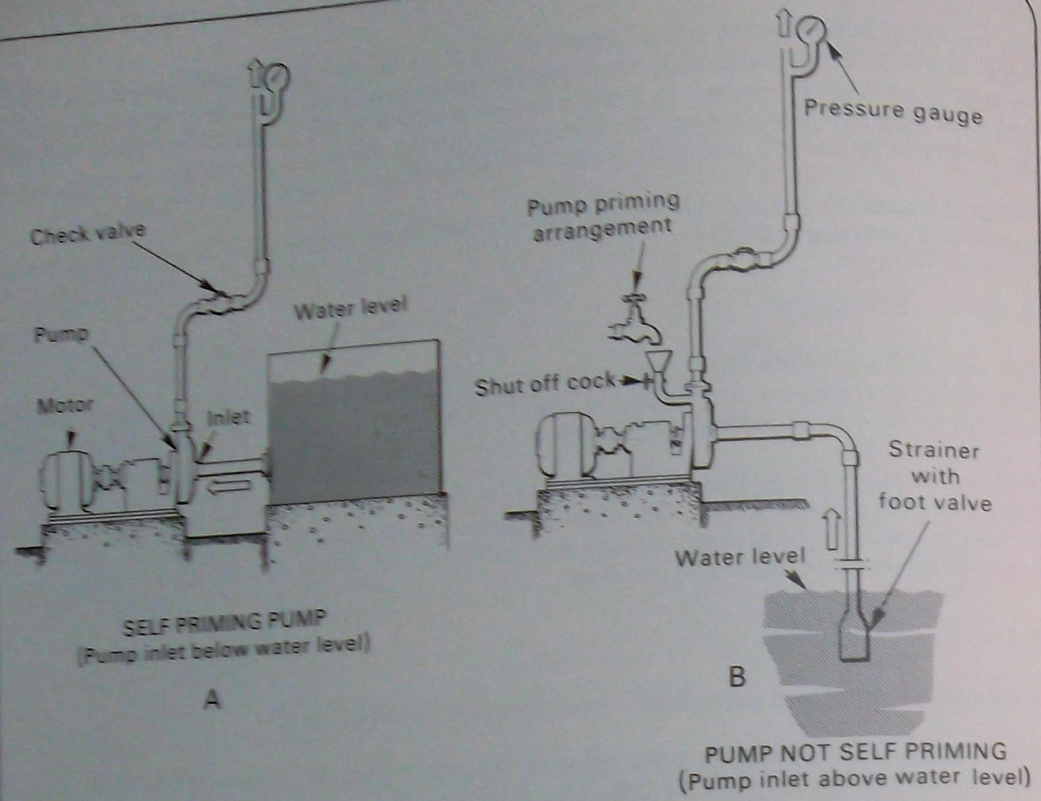
This is the ideal position for installing this type of pump as tedious priming (filling the casing with water before operating the pump) is eliminated.

Where the pump is fixed above the water to be pumped, the casing is generally filled from the delivery side and, to avoid priming of the pump every time it is put into operation, a non-return (check) valve is fitted to the bottom of the suction pipe. In this position this valve is referred to as a 'foot valve'. It must be remembered that the pump has no valves and, therefore, a non-return valve is required to prevent the water from draining back through the pump from the delivery pipe when the pump is not in operation.

5.1.5 Methods of drive

The impeller of the pump may be driven directly by a motor (direct coupled), or indirectly by belts or gears.

Accurate alignment of the pump shaft with the shaft of the motor is essential in the case of direct couple if undue strain and wear on the equipment is to be avoided.



TYPICAL PUMP INSTALLATIONS

5.2 RECIPROCATING PUMPS

A reciprocating pump is one which operates with a to-and-fro motion as described in the following sections.

5.2.1 The lift pump (Suction pump)

This is the simplest of the reciprocating pumps and is most commonly used to raise water from shallow wells, underground tanks, etc. where the water-level is less than 7.5 m below ground level. The pump is fixed above ground and manually operated; its use being restricted to areas where no electric power is available.

NOTE:

The term 'suction pump' is not strictly correct. The pump does not 'suck' but, in creating a lower pressure in the intake pipe during the upstroke of the piston, it allows atmospheric pressure to push water up into the pipe.

5.2.2 Construction

The lift pump consists of a bucket washer assembly into which is fitted a self-closing displacement valve moving up and down in a cylinder or barrel. A retaining or suction valve is provided where the intake or suction pipe leads from the barrel to the water to be raised.

In addition, a foot valve should always be fitted to the bottom of the suction pipe in order to retain water in this pipe and so eliminate a considerable degree of priming of the pump.

A strainer is also provided on the suction pipe to exclude foreign matter from the pump where it could score the barrel or bucket washers, or partially clog the valves, and so make them ineffective.

5.2.3 Operation

Upstroke

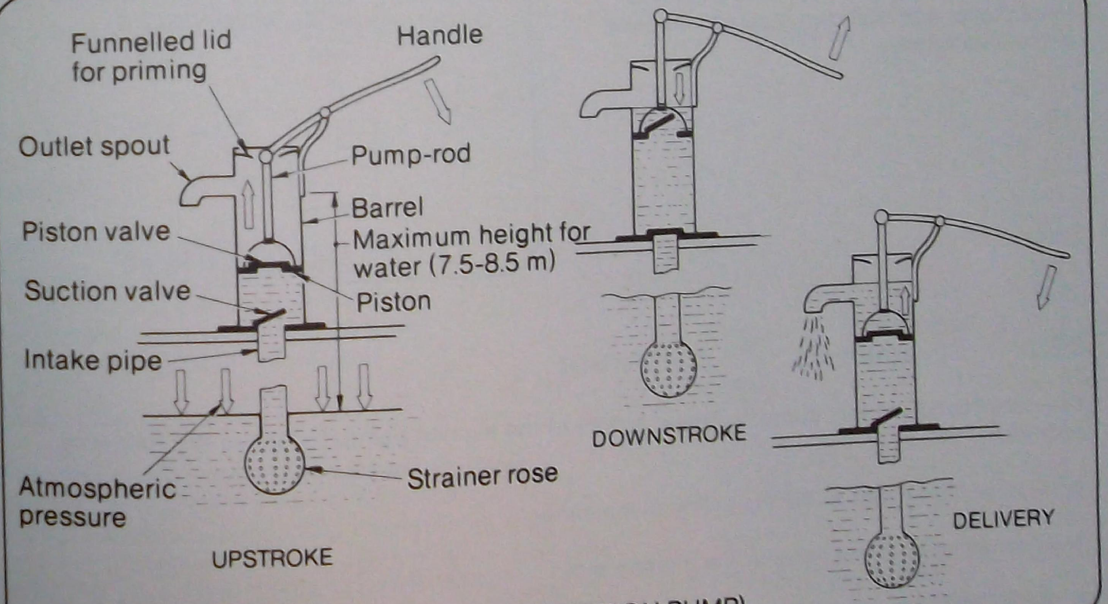
As the handle is pushed down, the bucket washer assembly is raised and the pressure in the lower part of the barrel reduced.

The atmosphere pressing down on the surface of the water in the tank, or the well, forces water up into the suction pipe and into the pump barrel thus restoring equilibrium of pressures.

Downstroke

On the downstroke of the bucket washer assembly (handle up), the water in the pump barrel is prevented from flowing back to the tank (or well) by the suction valve and foot valve.

The water below the bucket washer assembly is transferred through the displacement valve to above the bucket washer as the bucket washer assembly passes down through the water.



LIFT PUMP (SUCTION PUMP)

Next upstroke

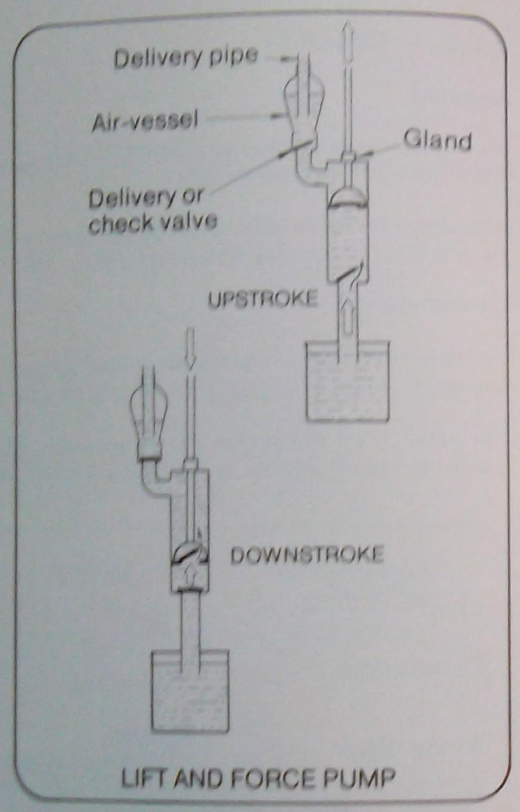
As the bucket assembly rises again, the water above the washer is lifted to the outlet from which it flows by gravity.

Water is forced into the lower part of the barrel as previously described.

Before pumping commences, the pump is primed with water to make both valves (seating by their own weight) and the space between the bucket washer and the barrel wall airtight.

5.3 LIFT AND FORCE PUMPS

When water is to be raised above the level of the pump, two stages are required. First, the water must be raised to the level of the pump with the assistance of the pressure of the atmosphere in a similar manner as that described for the lift pump. Second, the water must be forced to the higher level by the power of the pump alone. Such a pump is generally referred to as a lift and force pump, and is shown diagrammatically in the illustration.



LIFT AND FORCE PUMP

5.3.1 Construction

The construction of this pump is similar to that of the suction pump, but it has the following additions:

- A watertight gland at the top of the pump barrel.
- A retaining or check valve in the delivery arm.
- An air chamber, normally installed on the delivery arm immediately above the retaining valve, when the water is to be forced to a considerable height above the pump.

5.3.2 Operation

The movement of water in a lift and force pump is the same as that in an ordinary lift or suction pump but with the following additions on the delivery side:

Upstroke

Water is forced from the pump through the retaining valve into the delivery pipe.

Some of the water delivered from the pump will force its way into the air chamber and compress the air.

Downstroke

The retaining valve on the delivery side closes.

As the pressure in the delivery pipe is now less than in the air chamber, the air in the chamber expands and so tends to cause the water in the delivery pipe to flow in a continuous stream. This relieves the strain on the pump and prevents water hammer occurring in the delivery pipe.

5.4 THE DIFFERENTIAL PUMP

The illustration shows a differential lift and force pump in which the need for a watertight gland is eliminated by the differential cylinder and piston. No water passes this piston but its movement up and down creates, in the differential cylinder, a difference in pressure which is transmitted to the pump barrel.

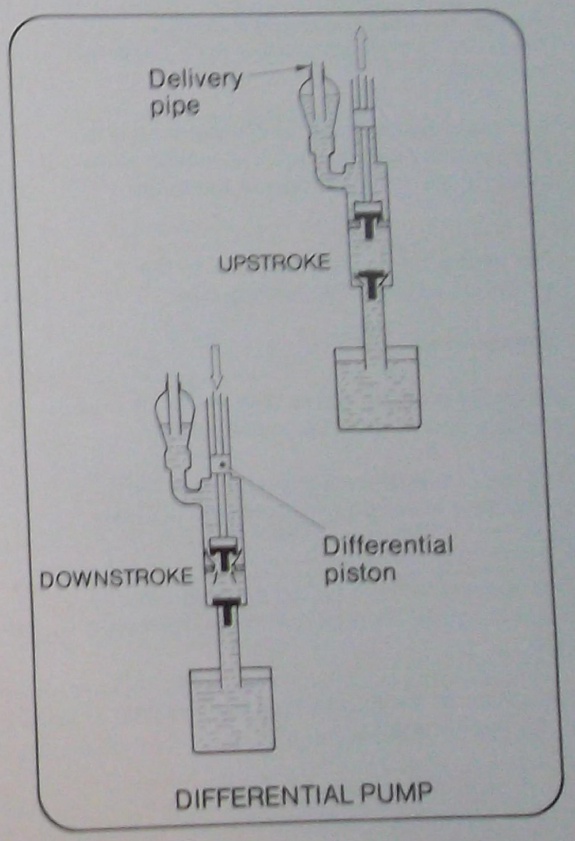
5.4.1 Operation

Upstroke

Water is raised to the pump by the atmospheric pressure and, above the bucket washer assembly, it is being discharged into the delivery pipe, air chamber and differential cylinder.

Downstroke

The differential piston forces water into the delivery pipe and air chamber while the bucket washer assembly also moves down and water passes through it. The inlet or retaining valve, now closed, prevents water from passing down the suction pipe.



DIFFERENTIAL PUMP

5.5 THE FORCE PUMP

This pump is used for a similar type of work as the 'lift and force' pump previously described. As in the previous type, the height to which the force pump will force water is entirely dependent upon the strength of the pump and fittings and the motive power operating the pump.

However, because this principle involves a compression stress on the pump rod, this rod is much heavier than that for a 'lift and force' pump.

5.5.1 Construction

The pump barrel is constructed of either cast iron, cast brass or drawn brass tube, the inside being machined to suit the plunger or piston. The plunger contains no valve but generally has a bucket washer facing downwards to ensure that no leakage of water to the upper portion of the barrel occurs.

The outlet, near the bottom of the barrel, is fitted with a retaining valve similar to that at the pump inlet from the intake or suction pipe. As before, the air chamber, when used, is installed immediately above the delivery valve.

5.5.2 Operation

Upstroke

As the plunger moves upwards, the pressure in the barrel below the plunger is reduced.

Atmospheric pressure forces water up into the suction pipe, through the suction valve and into the lower portion of the pump barrel.

The delivery valve is closed due to the weight of water in the delivery pipe.

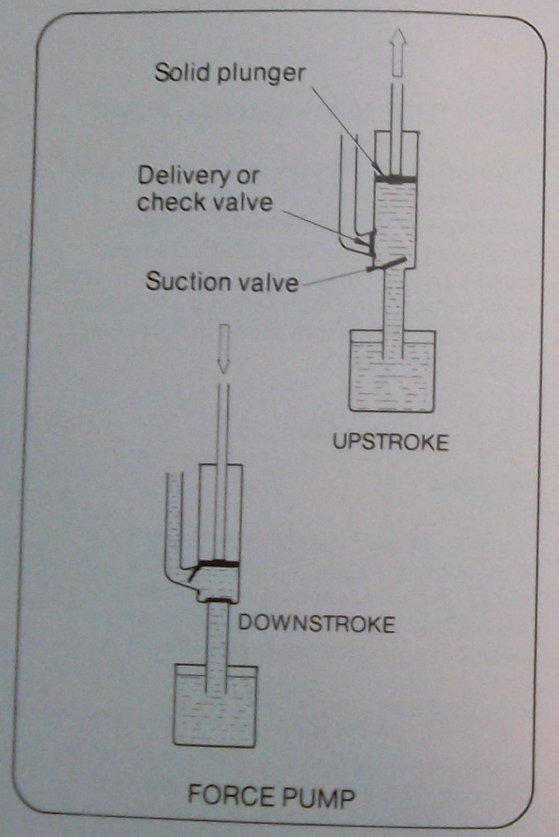
Downstroke

When the plunger moves downwards, it exerts a pressure on the water below it.

The suction valve closes on its seat, thus preventing water flowing down the suction pipe.

The delivery valve is forced open and the water is forced through it into the delivery pipe.

The action of the air chamber is the same as for the lift and force pump.



FORCE PUMP

5.6 THE DIAPHRAGM PUMP

This pump is a displacement pump used for pumping water through a low head. It has one distinct advantage over other types of pumps in that it has no close-fitting moving parts which could be easily damaged by foreign matter in the water. Because of this, it is ideally suited for pumping sludge or other liquids containing suspended matter.

5.6.1 Construction

The cast body is much larger in diameter, but shorter in length, than the barrels on the pumps previously described. A diaphragm of leather or heavy-gauge rubber is fitted to the top of the body and held in place by a steel clamping ring. Two valves, generally of brass and hinged at the top, are fitted near the bottom of the pump body — one for intake and the other for outlet. A steel actuating arm and pump rod complete the pump.

5.6.2 Operation

Upward movement of diaphragm

As the diaphragm moves up, the pressure within the pump body is reduced.

The intake valve opens and water flows into the pump due to gravity or the effect of atmospheric pressure as previously described.

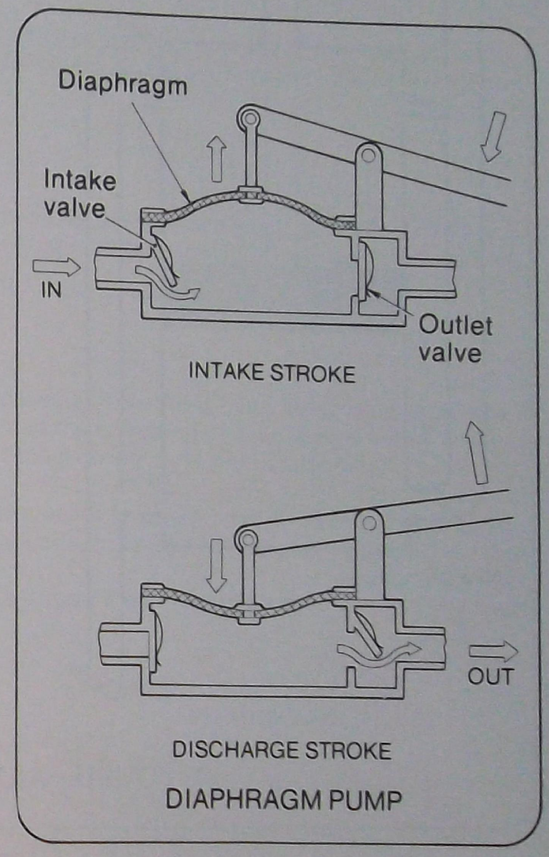
The outlet valve is closed.

Downward movement of diaphragm

When the diaphragm moves down, it exerts a pressure on the water below it.

The intake valve closes, thus trapping the water in the pump.

The outlet valve opens and the water is forced from the pump to the delivery pipe.



DIAPHRAGM PUMP

5.7 DOUBLE-ACTING RECIPROCATING PUMPS

The types of reciprocating pumps described so far do not give a uniform delivery of water and, for this reason, most are made double acting; water is delivered on each movement, or stroke, of the drive or the pump rod. With double-acting pumps, there is only a slight pulsating effect as the drive rod changes direction.

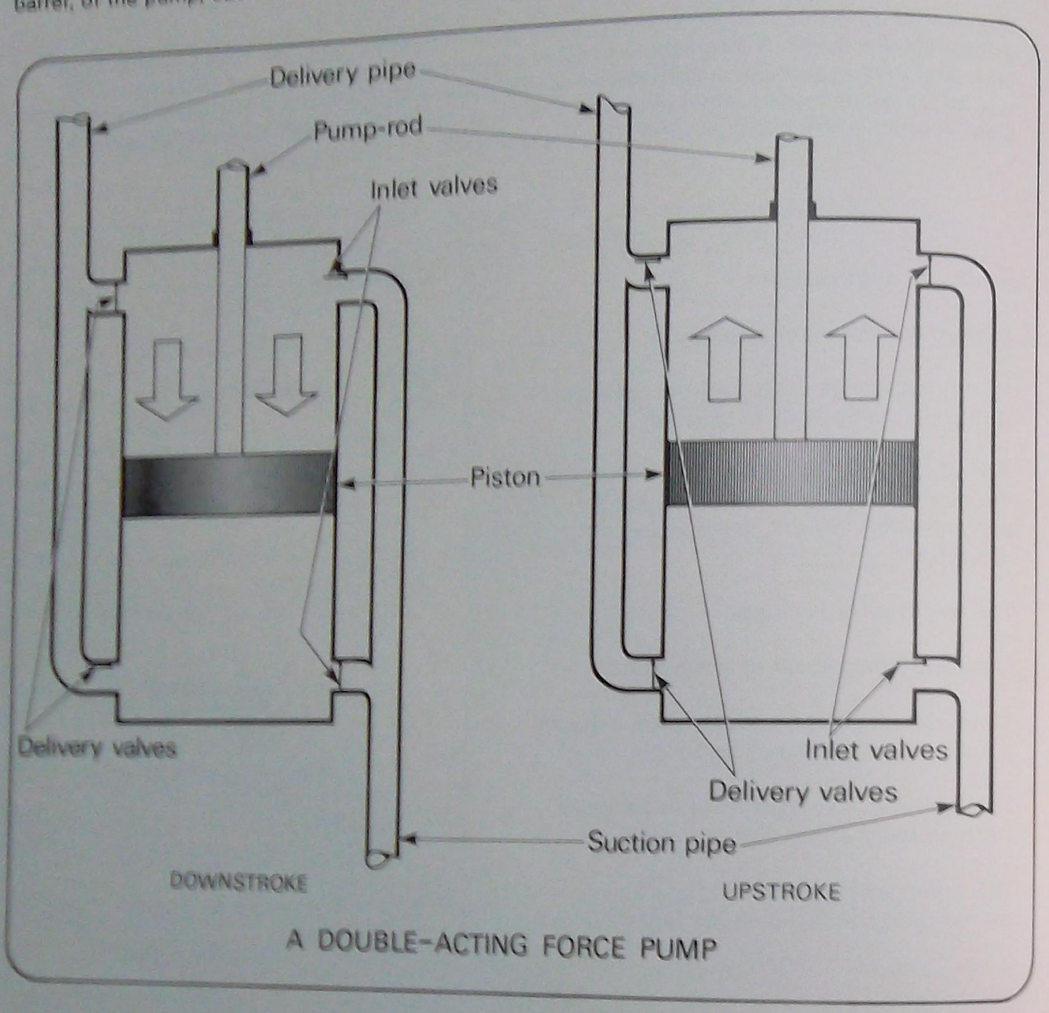
Only two types of double-acting pumps will be described in these notes. These are:

- Double-acting force pump
- Semi-rotary pump

5.7.1 The double-acting force pump

This pump is used for similar purposes to those described for force pumps but, as the pump is double acting, it has the ability to deliver twice the volume of water delivered by a single-acting pump of the same diameter and stroke.

The principle involves the use of a piston which has its stroke in the centre of the cylinder, or barrel, of the pump, each end of the cylinder being fitted with a suction and a delivery valve.



A DOUBLE-ACTING FORCE PUMP

5.7.2 Construction

The construction of this pump is simply a duplication of the force pump previously described — a piston being employed in the pump barrel and not a plunger. For convenience of installation, the inlet and outlet connections to the ends of the pump barrel are linked respectively to a manifold to give one inlet and one outlet connection.

5.7.3 Operation

Downstroke

On the downstroke of the piston, the inlet valve above the piston and the delivery valve below the piston are open.

Water below the piston is forced through the delivery pipe.

Atmospheric pressure forces water up the suction pipe, through the inlet valve, into the upper portion of the pump barrel.

Upstroke

The action on the upstroke of the piston is similar to that on the downstroke but the opposite valves are open, i.e. lower suction valve and upper delivery valve open.

It can be seen that this pump raises water to its own level and forces it above this level on both up and down strokes of the piston. The output of the pump on each stroke is equal to the volume of the piston displacement on each stroke.

5.8 THE SEMI-ROTARY PUMP

A semi-rotary pump is a double-acting lift and force pump, used where small quantities of water are required to be raised through a short lift and then forced to a comparatively low head. It is manually operated.

5.8.1 Construction

The body of the pump is generally of cast iron, the whole of the front plate being removable and fixed with bolts. With the exception of the handle and the operating spindle, which are of cast iron and rolled steel respectively, the remainder of the working parts are of cast brass.

The inner surfaces of the pump body are machined smooth to give a smooth fit of the activating arms thus reducing 'slip' which would result in reduced efficiency of the pump output.

The valves, being metal-to-metal, have ground-in seats and are hinged on one side.

5.8.2 Operation

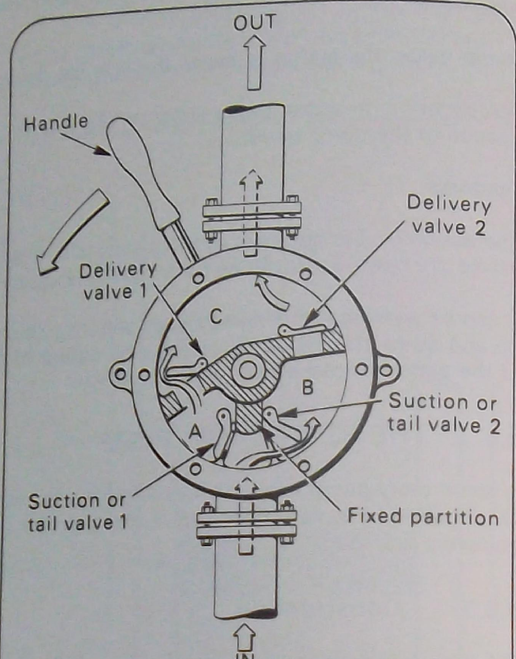
Handle rotated clockwise

- When the operating handle is moved in a clockwise direction, the actuating arms move in the same direction.
- A reduced pressure is formed at delivery valve No. 1.
- Inlet valve No. 1 opens and water is forced into the pump by atmospheric pressure.
- Inlet valve No. 2 remains closed, trapping the water below delivery valve No. 2 within the pump.
- Delivery valve No. 2 opens and allows the water below it to transfer to the area above the right-hand side of the actuating arm as it passes down through the water.
- The water above delivery valve No. 1 is forced into the delivery pipe.

Handle rotated anticlockwise

This action of the pump is similar to that already described when the handle is operated in the opposite direction, except that the opposite valves are closed.

The flow from a semi-rotary pump is continuous except for the momentary stoppage which occurs when the handle stops at the end of each stroke and the valves open or close.



CROSS-SECTION OF SEMI-ROTARY PUMP

NOTES

5.9 DEEP-WELL PUMPS

The suction lift of a pump is limited by the height to which the atmosphere will force water against the partial vacuum formed by the action of the pump.

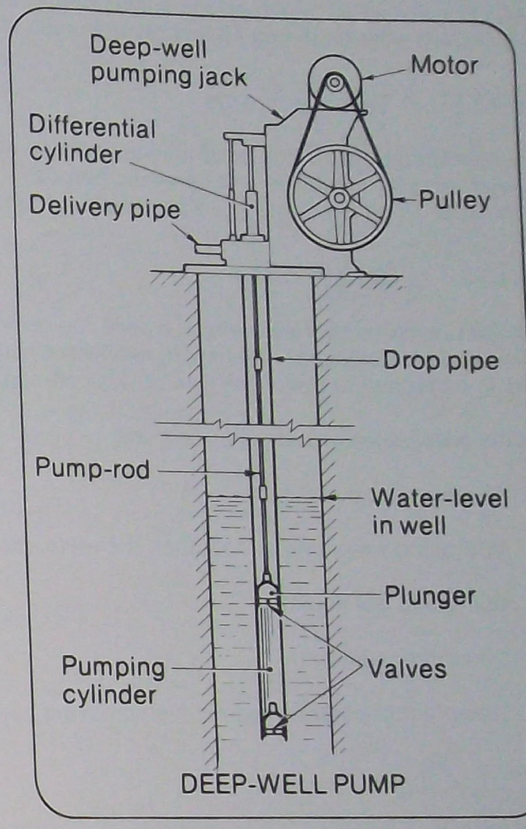
When the water is more than 7.5 m below ground, it is usually necessary to place the pump in or near the water and pump from there. When the pump is placed in this position, it is known as a deep-well pump. One type of deep-well pump is the pump-rod-operated deep-well reciprocating pump.

5.9.1 Operation

The operation of this pump is similar to the suction-and-lift pump. It will be noticed that the outlet is in the top of the pump and the bucket washer assembly is operated by a pumping jack through the pump rod.

5.9.2 Maintenance

Deep-well pump-rod-driven reciprocating pumps are expensive and require continual maintenance. The work of withdrawing the drop pipe and pump-rods for replacement of parts in the pump is very slow and tedious because the pump may be several hundred feet below ground level.



DEEP-WELL PUMP

5.10 ROTARY PUMPS

5.10.1 Gear pumps

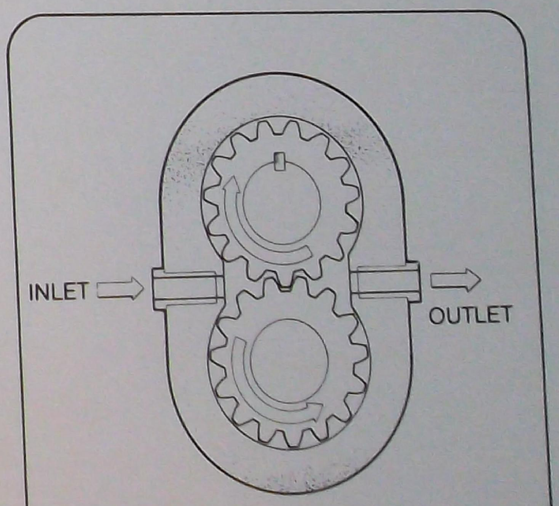
A gear pump is a simple form of a rotary pump used for pumping water from a short suction lift to varying pressure heads such as from storage tanks at ground level to overhead tanks.

5.10.2 Construction

The machined cast brass body, with a removable face plate, houses two gears, each of which is mounted on a steel shaft supported by bearings in the body and the face plate. One gear, driven by a motor, forces the other gear to rotate in the opposite direction. An inlet and outlet are provided in the body of the pump.

5.10.3 Operation

As the gears rotate in opposite directions, water is picked up in the disengaged teeth on the inlet side, carried outwards and around the pump to the outlet side. The close fit between the gear teeth and between the gears and the machine body prevents the water from returning to the inlet side.



GEAR PUMP

5.10.4 Installation

A gear pump should be installed below the level of the water to be pumped. This ensures priming of the pump at all times and eliminates the possibility of it being run dry which could cause excessive wear on the pump and result in loss of pump efficiency.

5.10.5 Turbine pumps

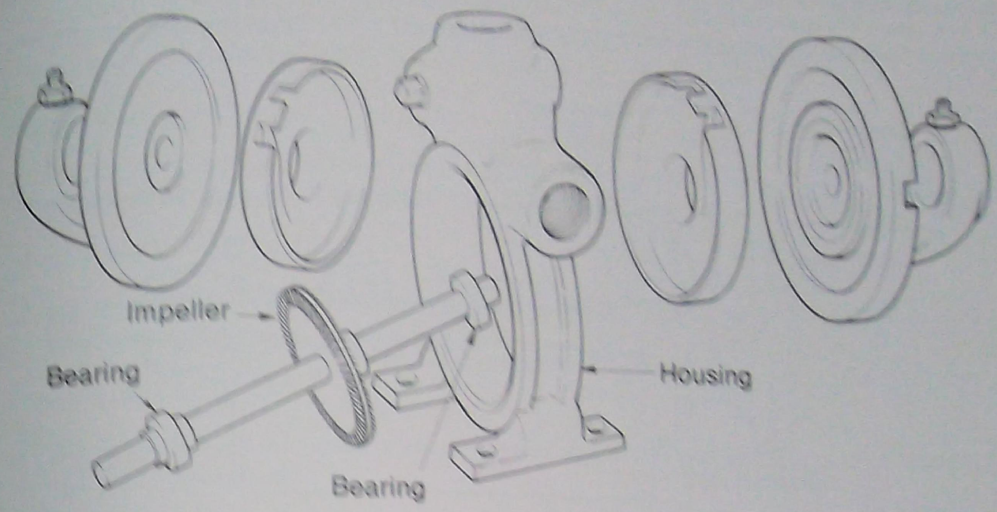
Turbine pumps are being used in increasing numbers for pumping a variety of liquids, including water, for both industrial and domestic purposes. They may be either single-stage or two-stage, the latter being used when pumping against high-pressure heads.

5.10.6 Construction

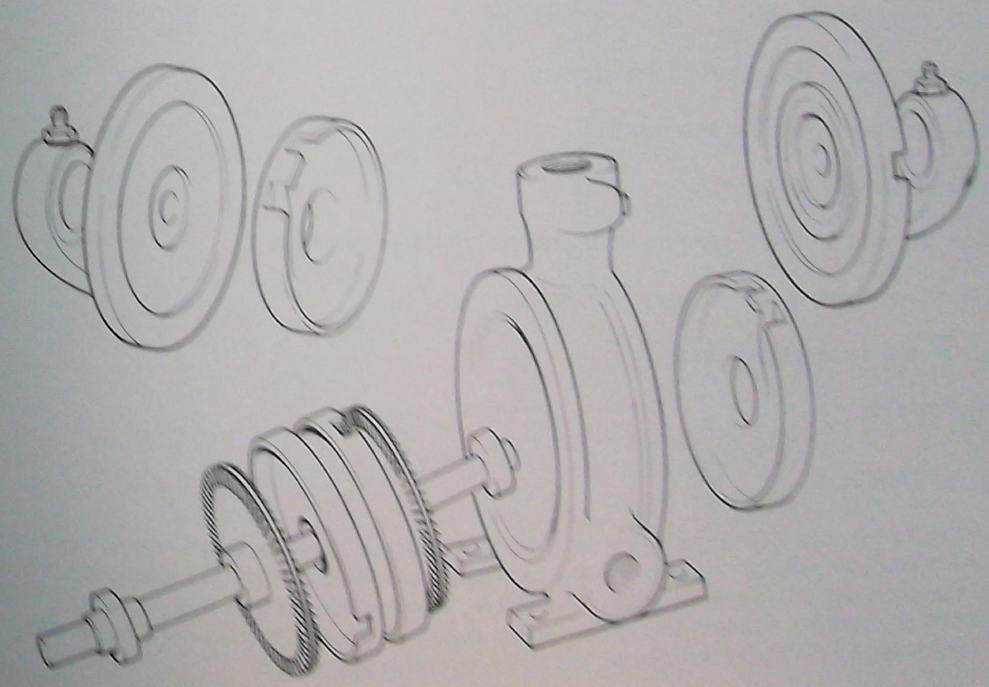
These pumps consist basically of a cast-iron body in which the bronze multi-vane impeller, mounted on a stainless steel shaft, revolves. Channel rings are provided to give a close fit around the impeller and to direct the flow of water through the pump.

Some advantages of turbine pumps are:

- Suction lift up to 8.5 m.
- Will pump water and air together; therefore, no vapour locks in pump.
- Will pump hot liquids.
- Quiet in operation.
- Suitable for operation against high-pressure heads.



SINGLE STAGE

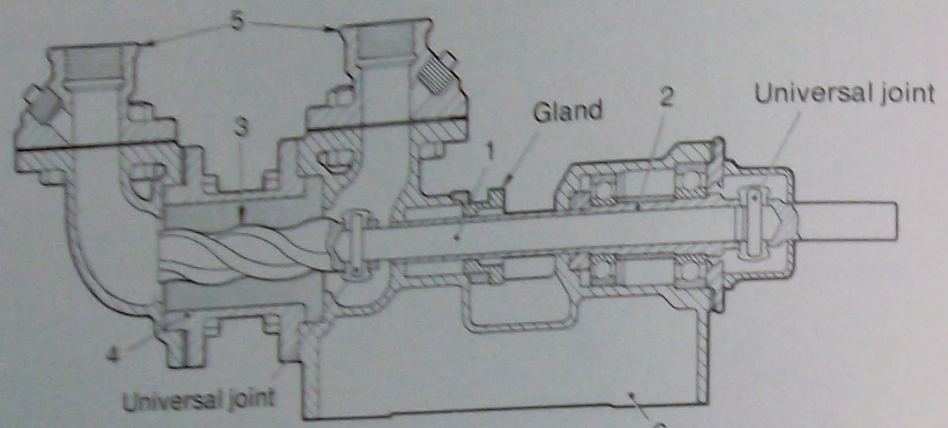


TWO STAGE

TURBINE PUMP

5.10.7 The mono pump

This pump is unique, yet simple in design. It incorporates the advantages of the reciprocating and centrifugal pumps and may be used for pumping water or liquids containing suspended matter in agriculture, food, cement, coal mining, quarry, engineering, paper and other industries.



MONO PUMP

5.10.8 Construction

The main component parts of this pump are:

- Drive shaft, running in ball bearings (1).
- Universal drive to the rotor (2).
- Rotor or a hard, corrosion-resisting metal, specially twisted to shape (3).
- Specially designed stator of natural or synthetic rubber (4).
- Suction and delivery branches (5).
- Metal base (6).

5.10.9 Operation

As the shaft rotates, the rotor turns within the stator. The design of these two parts is such as to produce a screwing motion and a constant seal between them. Because of the efficiency of this seal, this pump is self-priming to a suction lift of 8.2 m. Water is forced into the pump by atmospheric air pressure, screwed through the pump and forced through the outlet to heads of approximately 45 m for single-stage pumps and 90 m for two-stage pumps.

The two-stage pump has an additional twist in the rotor and forms two seals with the stator.

5.10.10 Characteristics

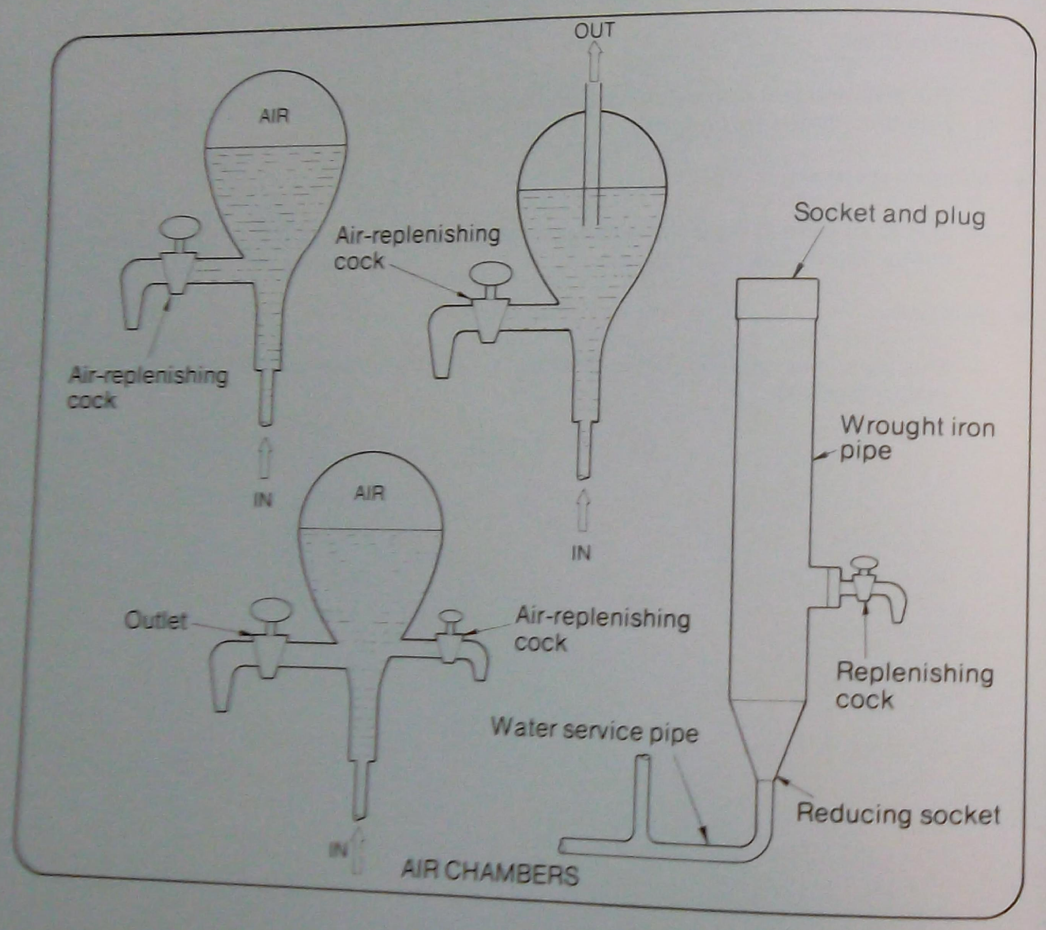
- Self-priming
  - Due to the highly efficient seal between the stator and rotor, this pump is self-priming to a suction lift of 8.2 m. The pump will operate with any proportion of air and water and will run from zero inflow up to the full capacity, provided there is sufficient water present to lubricate the stator and rotor.
- Positive displacement
  - The rotary motion of the rotor and the continuous flow of water from this pump give the combined advantages of the reciprocating and centrifugal types.
- Uniform flow
  - The displacement of water in the pump is constant for any given rotor speed, thus giving a uniform discharge of water.
- Abrasion resistant
  - Due to its design, the pump is abrasion resistant. It may be used for pumping liquids containing sludge, etc.
- Simplicity
  - This pump has only one gland, no valves, requires no lubrication, and worn parts can be readily replaced.

NOTES

5.11 AIR CHAMBERS

An air chamber is installed with any type of pump likely to cause water hammer, or in cases where the strain on the pump must be relieved. Pumps most likely to require an air chamber are the single-acting reciprocating types.

Air chambers must be installed in an upright position, close to the pump. As the water is discharged intermittently from the pump, the air in the chamber is compressed so absorbing any hydraulic shock likely to cause water hammer. As the downstroke of the pump takes place, the air in the chamber forces water from the chamber into the delivery pipe, thus providing a reasonably constant flow of water through this pipe and relieving the strain on the pump.



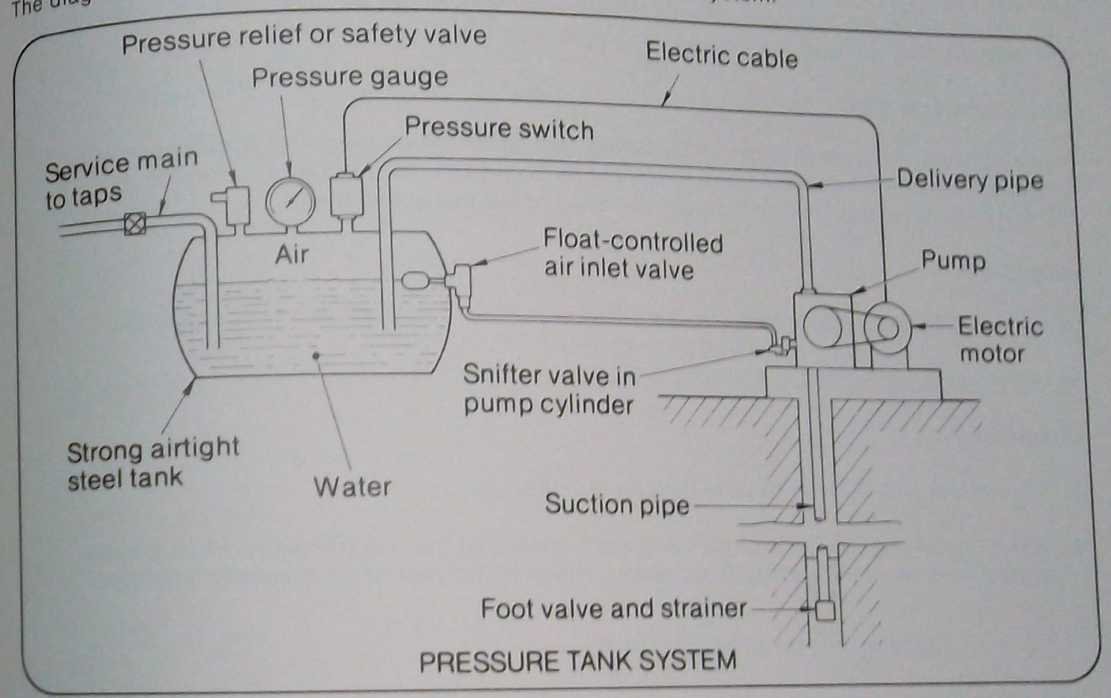
AIR CHAMBERS

5.12 HYDROPNEUMATIC SYSTEMS

Where there is sufficient water in a well, small reservoir or low-level storage tanks, and electricity is available to drive a motor, a special pumping outfit operating on what is known as the hydropneumatic system may be installed. Such an outfit supplies water under pressures of from 275 kPa to 482 kPa directly to the draw-off taps.

In such a system, the pump may be of any type but, for small installations, it is usually an ordinary double-acting reciprocating or a turbine pump. In addition to the normal pumping equipment, there is a storage cylinder made of steel plate.

The diagram shows a typical hydropneumatic or pressure tank system.



PRESSURE TANK SYSTEM

5.12.1 Operation

Draw-off valve closed

- The water is forced by the pump through the delivery pipe into the pressure tank.
- As the water-level in the tank rises, the air in the tank is compressed.
- An automatic pressure switch stops the pump motor when the pressure in the tank reaches the maximum value.

Draw-off valve open

- The air cushion forces water along the service pipe and out of taps at high pressure.
- The pressure in the tank gradually falls as the air expands.
- The pressure falls below the desired minimum and the pressure switch automatically starts the pump motor.
- Water is pumped into the tank.
- The tap closes — maximum pressure is restored — motor switches off.

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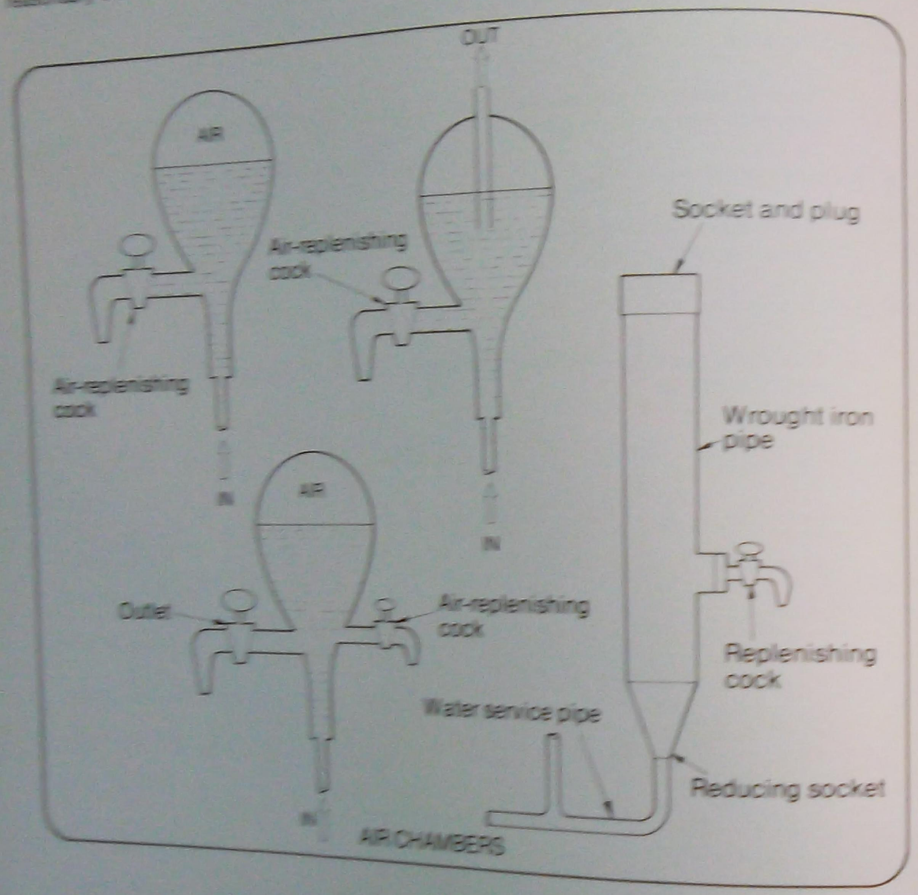

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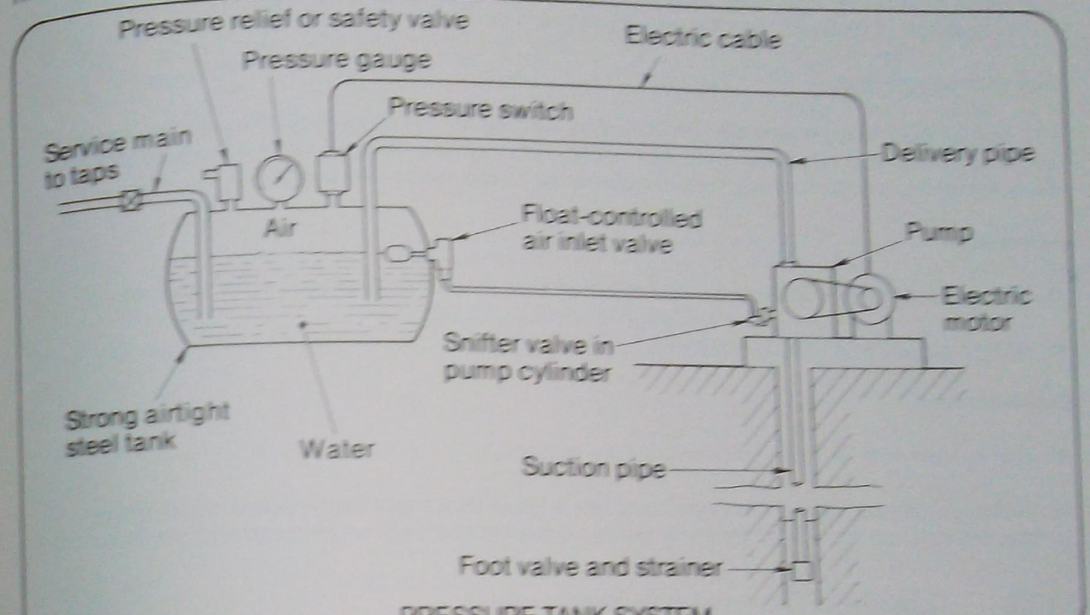

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- Water is pumped into the tank.
- The tap closes — maximum pressure is restored — motor switches off.

Safety valve

For safety, and to protect the motor from overload, a relief valve is provided to release the pressure when it rises above the safe value. This is in addition to the usual motor overload cut-out.

Replenishing air in pressure tank

The air under pressure in the tank tends to be absorbed into the water and the system will become waterlogged unless there is some means of replenishing the air.

An automatic air-volume control with a float in the pressure tank opens a valve to admit air when the water-level in the tank rises above a certain level. This allows air to be drawn into the pump on the suction stroke and then forced into the tank on the delivery stroke.

Size of pressure tank

The size of the pressure tank has an important bearing on the efficiency of hydropneumatic systems. A common household size is 180-270 litres, but the trend today is to reduce this capacity which results in more frequent operation of the motor and pump.

Advantages

- The cost of the pressure tank is usually less than that of an overhead tank and stand.
- A high-pressure system is achieved.

Disadvantages

- The system fails in times of power supply cut-offs.
- Water containing iron compounds becomes a great deal more discoloured when greater quantities of air are absorbed under pressure than is the case at atmospheric pressure.

5.12.2 Diaphragm-type pressure tank

This system consists essentially of a pre-pressurised tank (generally of stainless steel) with a moulded polypropylene liner and a sealed-in diaphragm that prevents contact of the water with air in the tank. The diaphragm is a specially compounded material that imparts neither odour nor taste to the water and has a long life.

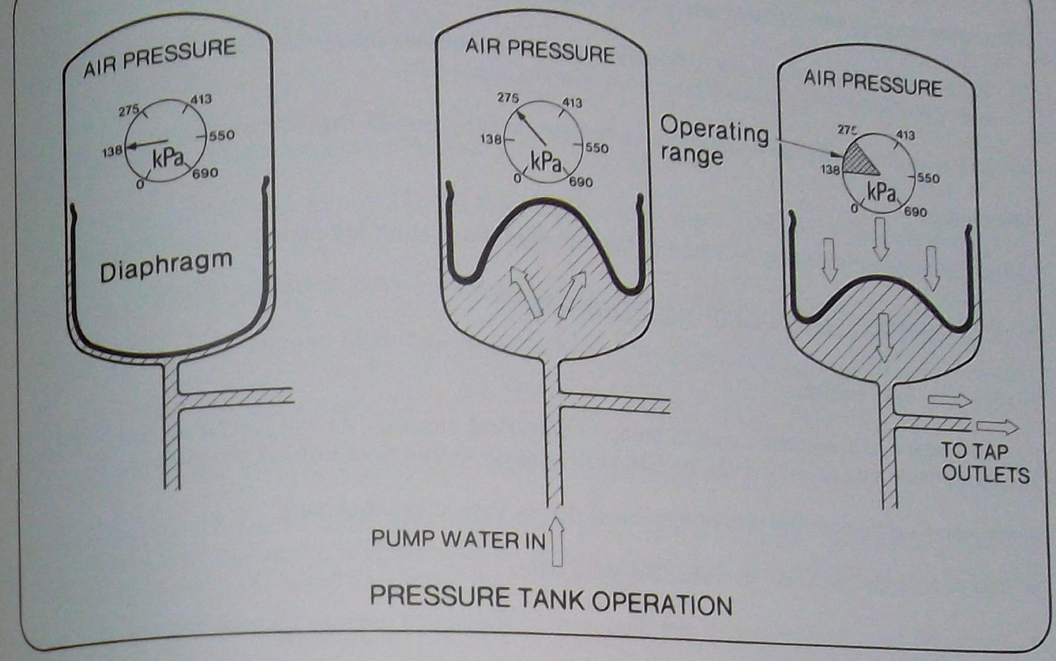
5.12.3 Operation

Before starting the pump, the cylinder is charged with air to a pressure of 138 kPa through the air-charging connection at the top. When the pump first starts to operate, no water will enter the tank until the pressure developed by the pump exceeds the 138 kPa charge pressure behind the diaphragm.

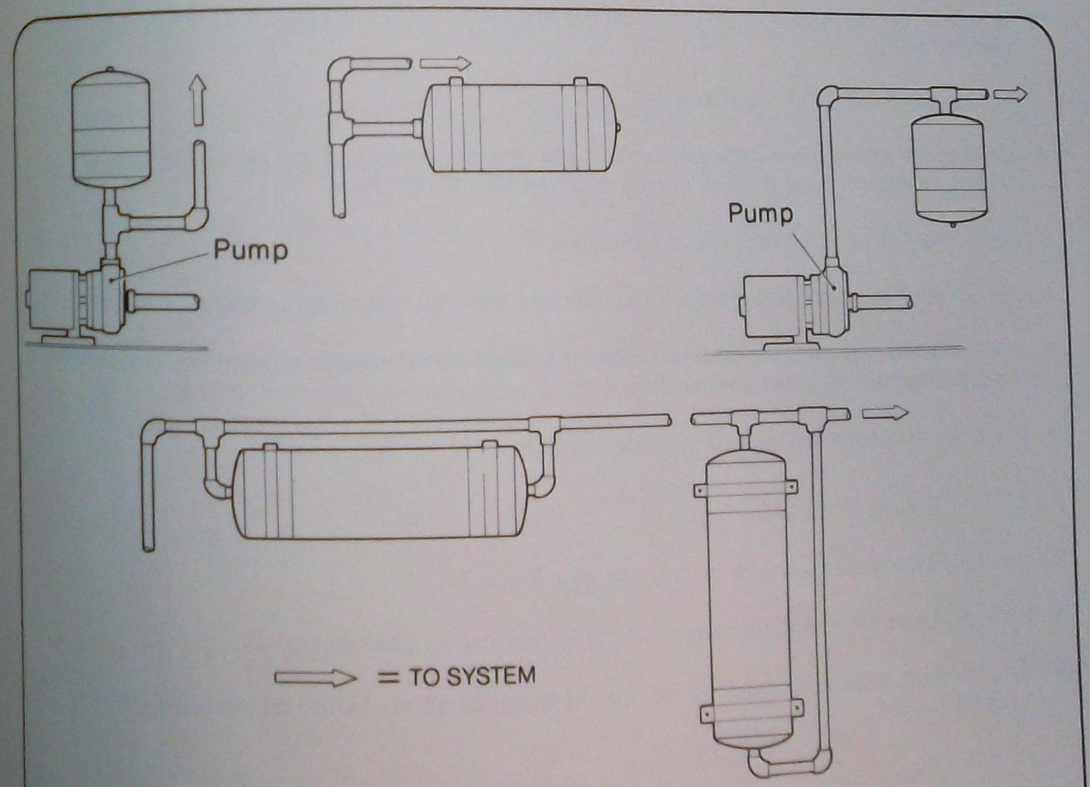
As the water enters the pressure tank, the diaphragm begins to invert and the air pressure in the tank increases. When the pressure reaches 275 kPa, the pump stops. The water pressure in the tank is also 275 kPa.

When water is drawn-off through a tap, the air pressure behind the diaphragm forces water from the tank through the service pipes. When the air pressure in the tank again reaches 138 kPa, the pump starts and replaces the water drawn from the tank.

The cut-in and cut-out pressures are adjustable.



PRESSURE TANK OPERATION



METHODS OF INSTALLING DIAPHRAGM-TYPE TANK SYSTEMS

Advantages

This system gives two distinct advantages over the ordinary pressure tank method. These are:

- No discoloration of the water occurs due to iron oxide because the diaphragm prevents the water and air in the pressure tank from coming in contact.
- The tank cannot become waterlogged for the same reason as that stated above.

Installation

Some methods of installing this type of hydropneumatic system are shown in the illustration.

5.13 INSTALLING PUMPING EQUIPMENT

5.13.1 The pump

It is essential that the correct type of pump of sufficient capacity for the job be selected for each situation. When any doubt exists, the advice of experts in this field should be obtained.

When installing pumps, the following general points should be observed:

- The pump must be securely fixed to a solid base.
- The pump must be level and, if direct-coupled to the motor, ensure correct alignment of pump and rotor shafts.
- Install the pump as close as practicable to the level of the water to be pumped.
  - Some types of pumps should be installed below water-level.
- If belt-driven, make sure correct size pulleys are used to drive the pump at the recommended design speed.
- Ensure accessibility for maintenance.
- Make sound connections between suction and delivery pipes and the pump flanges, or unions, to allow the pump to be readily removed for maintenance.
- Check that the pump is adequately lubricated.
- Inspect shifting bonds and glands for soundness and that the pump is free to operate.
- Make sure that the pump is clean and free of foreign matter before putting it into operation to avoid scoring of machined surfaces.
- Do not air chamber if the type of pump warrants it.

5.13.2 The suction pipe

Points to note in connection with the suction pipe are:

- It should be as short and direct as practicable, without 'to' preference.
- If not relative, it must have a good fall with easy radius bends when necessary, and all joints tied to straight.

- The lower end should be fitted with a foot valve and strainer to exclude foreign matter from the pump and to retain water in the suction pipe. The area of the openings in the strainer should be at least twice that of the cross-sectional area of the suction pipe.
- Correct diameter which should not normally be less than the size of the pump inlet.
- Securely fixed.
- Be of sound corrosion-resistant materials.
- End of the pipe placed well below the lowest water-level when pumping from underground supplies.
- Maximum height of pump above lowest water-level to be 7.6 m.
- Avoid rises in the suction pipe that may cause air locks to occur.

5.13.3 The delivery pipe

The following points should be observed when installing delivery pipes:

- The diameter should be sufficient to eliminate strain on the pump and on the fittings through excessive resistance, but it should not be so large that it causes excessive back pressure on the pump due to the weight of water held in the pipe.
  - Generally, the delivery pipe is at least one nominal size smaller than the suction pipe.
- The line should be as short and as direct as possible with easy radius bends when necessary to change direction and be provided with a good fall and free of possible air locks.
- A full-way control valve should be fitted near the pump.
- The pipe should be firmly fixed but with allowance for expansion and contraction in long runs.
  - Bellows-type expansion pieces also isolate any vibration in the system.
- An air chamber is to be fitted as necessary.
- A non-return valve should be provided particularly when reciprocating pumps are used.

5.13.4 Pump valves

The valves fitted in reciprocating pumps are vital to their operation. It follows that these valves must be in good order with sound seats if the pumps are to operate at maximum efficiency. The two types of valves generally used are:

- Metal-to-metal
- Leather-to-metal

Metal-to-metal

This type of valve generally consists of a circular (rectangular in semi-rotary pumps) brass casting with a machined lower face ground-in (lapped) to a seating in the pump body or bucket washer assembly, etc. The round valves operate vertically and pumps incorporating their use must be installed in an upright position.

The rectangular-shaped valve is hinged on a brass pin. When servicing pumps with valves of this nature, all valves should be checked for freedom of movement on the pivot pins.

Metal-to-metal valves are usually very serviceable and give little trouble, provided that the liquid pumped is kept free of foreign matter.

Occasionally, the face of the valve or seat will become scored by foreign matter. Lapping of these parts then becomes necessary to restore the efficiency of the pump. A fine liquid abrasive should be used on the two faces and the valve rotated backwards and forwards on its seat until all scoring has been removed. (Deeply scored valves and seats should be renewed.) The seating of the valve should then be tested by filling the pump with water.

Leather-to-metal

A piece of good-quality leather is fixed on one end with the other end resting on a metal seat. A flat brass weight is screwed to the top of the leather to keep it flat and to hold it down in position to seal the pump. Hinging is provided by the flexibility of the leather.

Because the leather is softer than the metal and so wears more quickly, the only servicing required with this type of valve is the replacement of the leather.

Bucket washers

These are made from good-quality leather and are obtainable in sizes to suit the various diameters of the pump barrels.

When fitting bucket washers to pumps, care should be taken to ensure that adequate clearance between the pump barrel and the dry bucket washer is made to provide for expansion of the leather when wet. Binding of the pump may result from too tight a fit, while loss of pump efficiency will result if the fit is too loose.

5.14 THE VANE PUMP

This type of pump is not widely used in water supply applications, but the small portable ones may be used for pumping out sumps, flooded pits or for ornamental fountains.

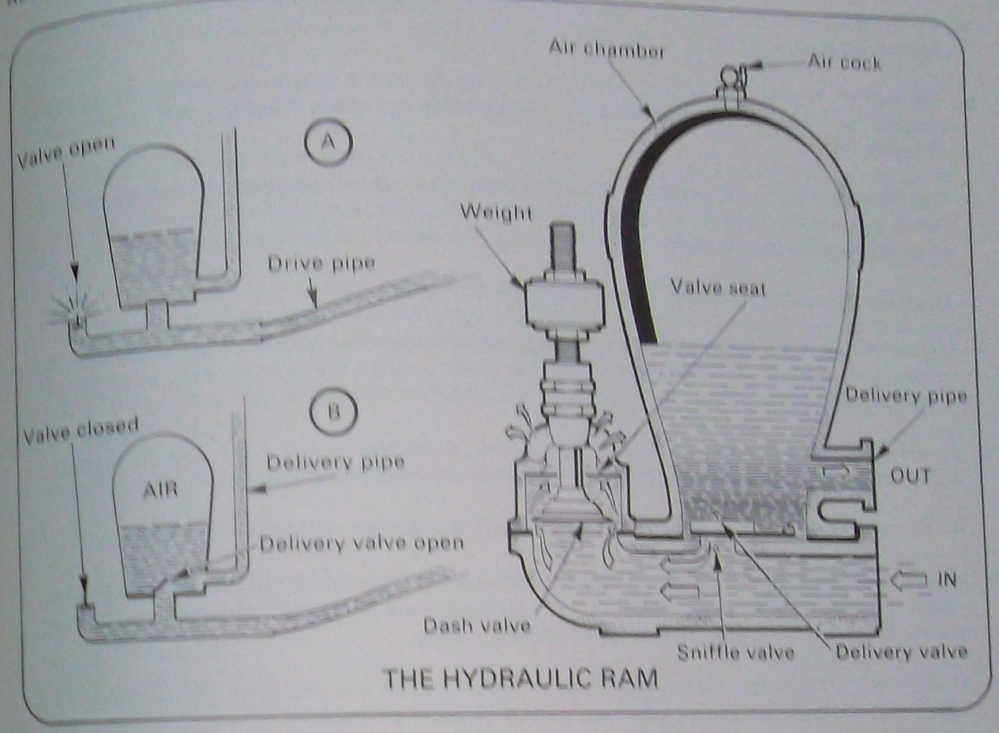
In its simplest form, it consists of a rotor with flexible vanes made of neoprene which turn inside a pump housing.

The rotor is mounted on a shaft that projects through the cover of the pump and which can be coupled to a small electric motor.

The pumping chamber is so shaped between the inlet and outlet ports that the vanes are forced closer together when they are opposite the outlet port so 'squeezing' the water through it. This type of pump is self-priming and its rotor can be spun either way to reverse the direction of flow.

5.15 THE HYDRAULIC RAM

The illustrations show a cross-section of a hydraulic ram and a diagrammatic representation of its working. Note that, for clarity, the delivery pipe is shown in the same plan as the drive pipe. Actually, the pipes are usually at 90° to one another.



THE HYDRAULIC RAM

In a hydraulic ram the force that is produced by suddenly stopping a moving column of water is used to raise some of it under pressure to a higher level. Proper operation of a hydraulic ram depends on:

- An adequate supply of water.
- Its location relative to the level of the water supply source.
  - The ram must be located well below that.

The ram consists of:

- An air vessel mounted over a drive pipe.
- A dash valve mounted at the end of the drive pipe.
- A delivery valve mounted at the junction of the air chamber and drive pipe.
- A sniffle valve.
- A delivery pipe located near the bottom of the air chamber.

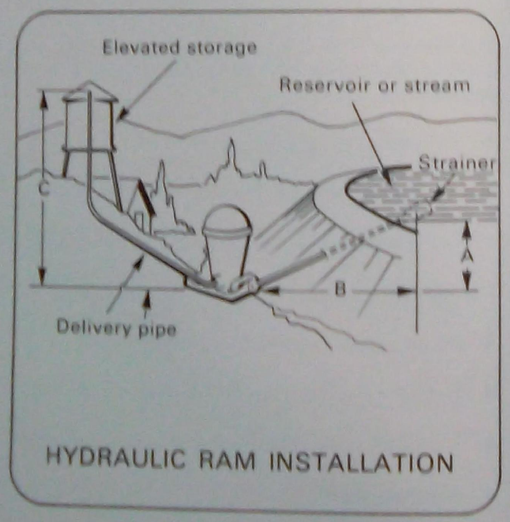
The operation of the hydraulic ram is as follows:

- Water from the supply source flows down the drive pipe and escapes through the dash valve which can move freely up and down in its guide, and is held open by the weight attached to its stem (A).
- As the velocity of the water increases, it produces enough pressure to force the dash valve against its seat.
- The sudden stop of flow produces a rebound wave (similar to that which would create water hammer) which is sufficient to force the delivery valve upward and allow water into the air chamber (B).
- This halting of the water column in the drive pipe is so sudden and violent that the recoil moves against the water coming from the supply source and, in doing so, relieves the ram of all pressure allowing the dash valve to drop and the delivery valve to close.
- The cycle is repeated as water moves down the drive pipe again.
- Meanwhile, as water continues to enter the air chamber, the air in it is compressed and this in turn, because it wants to expand, forces the water through the delivery pipe in an almost steady stream.
- As the air contained in the air chamber is gradually absorbed by the water and discharged with it through the delivery pipe, there is a need to replace that air so lost.
  - Air can be admitted to the air chamber through an air cock fitted to it.
- Alternatively, recharging the air chamber can be done automatically by one or more sniffle valves. The sniffle valve is a one-way valve to atmosphere allowing air into the drive pipe, as shown. The valve is located just below the delivery valve.
- At each recoil, the sniffle valve allows a small amount of air into the drive pipe and this air is forced into the air chamber with the next charge of water entering it.

The illustration shows a typical hydraulic ram installation.

Hydraulic rams are manufactured to suit a variety of conditions and, when ordering a ram, it is important to specify:

- The capacity of flow at the source of supply.
- The vertical distance (A) between reservoir level and ram.
- The distance (B) over which the fall occurs.
- The vertical height (C) over which the water is to be raised.
- The amount of water required per day.



HYDRAULIC RAM INSTALLATION

In installing a hydraulic ram it is important to ensure:

- That the drive pipe is of sufficient length, as straight as possible and of even fall.
  - The length should never be less than the vertical height (C) to which the water is to be raised. The minimum length should not be less than 15 m.
- The drive pipe diameter is large enough to obtain a fast flow for a smart closure of the dash valve.
  - Usually, the drive pipe is twice the diameter of the delivery pipe.
- The strainer fitted at the inlet to the drive pipe is kept at least 300 mm below the surface of the supply source to prevent air being drawn into the drive pipe.

Proper hydraulic rams can work adequately on falls as small as 600 mm, but preferably the fall should be between 1.5 and 1.8 m.

Each 300 mm of fall in the drive pipe corresponds roughly to a water-raising height of some 6 m or more, but as delivery height increases, the ram capacity rapidly decreases.

For rule-of-thumb calculations, it can be taken that an average ram will have the following performance:

- It will force about ¼ of the water in the drive pipe 3½ times the height of the fall.
- It will force about 1/8 of it to a height of 6 times the fall.
- It will force about 1/16 of the drive water to a height of 10 times the fall.

NOTES

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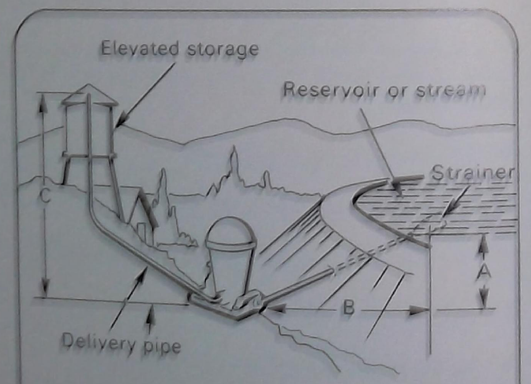

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  - The length should never be less than the vertical height (C) to which the water is to be raised. The minimum length should not be less than 15 m.
- The drive pipe diameter is large enough to obtain a fast flow for a short closure of the dash valve.
  - Usually, the drive pipe is twice the diameter of the delivery pipe.
- The strainer fitted at the inlet to the drive pipe is kept at least 300 mm below the surface of the supply source to prevent air being drawn into the drive pipe.

Proper hydraulic rams can work adequately on falls as small as 600 mm, but preferably the fall should be between 1,5 and 1,8 m.

Each 300 mm of fall in the drive pipe corresponds roughly to a water-raising height of some 6 m or more, but as delivery height increases, the ram capacity rapidly decreases.

For rule-of-thumb calculations, it can be taken that an average ram will have the following performance:

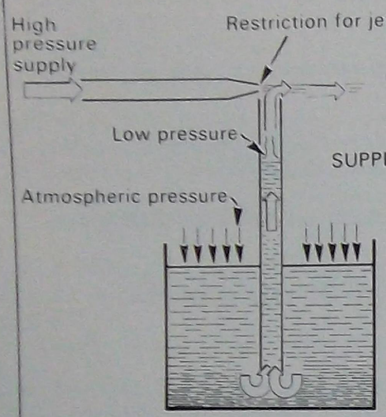
- It will force about ¼ of the water in the drive pipe 2½ times the height of the fall.
- It will force about 1/8 of it to a height of 5 times the fall.
- It will force about 1/16 of the drive water to a height of 10 times the fall.

NOTES

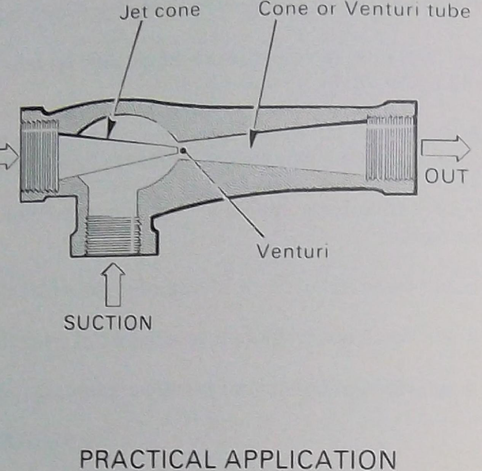
5.16 EJECTORS

Ejectors work on the principle that if a stream of air or liquid is passed at right angles and at high speed over the end of an open tube, the pressure in the tube will be lowered.

This is due to the fact that the restriction to the supply flow which occurs in the nozzle of the job produces an increase in velocity of the air or liquid flow, but at the same time, this velocity increase is responsible for the lowering of pressure at the point of the flow restriction. That point is called 'The Venturi'.



EJECTOR PRINCIPLE



PRACTICAL APPLICATION IN EJECTOR UNIT

If now the open tube is lowered into a fluid, the lowered pressure at the top, as a result of the high-speed stream over it, will allow the atmospheric pressure to push the fluid up into this suction tube and be ejected with the high-pressure, high-speed stream that passes over it. This process will continue until all the water has been removed from the container.

In theory, because atmospheric pressure can support a water column of some 10 metres, it would be possible for an ejector to raise water to this height. In practice, because of imperfections in design, installation and the available operating pressure, the best that can be obtained in raising height is usually between 4.5 to 5.5 metres at a supply operating pressure of between 560 to 700 kPa.

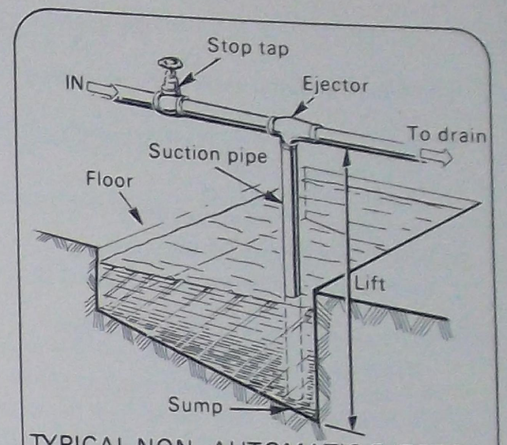
The reduction in pressure that is obtainable in the Venturi is very small and this makes it necessary to keep the suction pipe short, usually between 300-450 mm. Alternatively, the 'lift' to the ejector can be eliminated by arranging it to operate from below the water that is to be raised.

For water-raising purposes two types of ejector can be used:

- The non-automatic type.
  - — The high-pressure supply to operate the ejector must be turned on and off by hand.
- The automatic type.
  - — In this type, the ejector comes into operation when the water-level in the sump reaches a predetermined level.

5.16.1 Non-automatic ejectors

These are often installed to remove seepage water from cellar floors. The floor of the cellar should be graded downwards to a suitable point where a sump can be built to collect the unwanted water. The ejector is then installed in the manner shown, or inside the sump and below the water. When the stop tap is opened to supply the ejector, the process explained earlier begins and continues until the sump water has been discharged to the drain. The tap is then turned off.



TYPICAL NON -AUTOMATIC EJECTOR INSTALLATION FOR CELLAR SUMP

5.16.2 Automatic ejectors

Water supply to the ejector is controlled by a valve which is connected by a level to floats weighted with lead shot. The floats are arranged above one another and connected by an A-frame arrangement to the valve-operating lever.

As the water in the sump rises sufficiently to reach the upper float, the combined buoyancy of the floats is sufficient to activate the lever, opening the valve and allowing high-pressure supply water to the ejector which then begins to remove the water from the sump.

When the water-level in the sump has dropped below the level of the lower float, the weight of the floats, with their lead shot, makes them drop also; the valve-operating lever is moved in the opposite direction and closes the valve, putting the ejector out of action until the water-level reaches the upper float once more.

In general, ejectors of this type are rather inefficient; they require large amounts of water to eject a relatively small amount of water from where it is not wanted. This is the main objection to their use.

THEY SHOULD BE USED ONLY WHERE AMPLE SUPPLIES OF WATER ARE AVAILABLE AND WHERE LOCAL WATER SUPPLY AUTHORITIES ALLOW THEIR INSTALLATION.

It must be emphasised that the plumber should, at all times, carefully follow the manufacturers' recommendations regarding the installation of all pumping equipment.

REVISION QUESTIONS

1. List 4 ways of water purification, describing briefly the processes that take place in each.

2. a Describe, using sketches if necessary, the working of:
   (i) a domestic filter
   (ii) the rapid sand filter
   (iii) the multi-unit pressure filter
   b What is meant by 'backwashing'?
   c Using a simple diagram explain how it is carried out in a rapid sand filter.

3. a There are two types of water hardness
   (i) what are they?
   (ii) what is their cause?
   (iii) how can each be removed from the water supply?
   b Describe the design and operation of the zeolite water-softening plant.
   c What is zeolite, what is its purpose in the plant, and how does it remove water hardness?

4. a Sketch and describe the working of a lift pump.
   b What would the effect on the working of the pump be, if:
   (i) the piston seal was faulty?
   (ii) the delivery valve was stuck open?
   (iii) the suction valve failed to close on the downstroke of the piston?
   c What arrangements would have to be made if the level of the water to be raised was 12 metres below the level of the suction valve of a lift pump?

5. a What is the purpose of an air chamber?
   b Describe its working with the aid of sketches.
   c Can an air chamber be fitted to the outlet side of a lift pump having an open-ended barrel? If not, why not?

6. Describe the differences between a lift pump and a force pump.

7. a Describe the construction of a centrifugal pump, using sketches if necessary.
   b Why are the impeller vanes shaped in a special way?
   c Why is the housing shaped the way it is?
   d Why should there be a check valve on the delivery side of such a pump?
   e Why is a check valve needed on the inlet side of a centrifugal pump that is not self-priming?
   f Describe the procedure of priming a centrifugal pump.

8. a What are the main requirements for the proper operation of a hydraulic ram?
   b What does the ram consist of?
   c Describe its operation.
   d Why should air be admitted to the ram and how is this done?
   e What are the main things to watch when installing a hydraulic ram?

9. a Discuss the principle on which the operation of an ejector is based.
   b How much 'lift' can be expected from such a device, and why is this?

6 FIXED GARDEN SPRINKLER

Garden sprinkling systems of this kind can be fixed in or above the ground. They are connected to a water service pipe and controlled by a stop tap. There are various sprinkler types available in either metal or plastic. Some are static and others rise from below ground level when the water is turned on and return underground when the water is shut off. Sprinkler nozzles, which are interchangeable, are made to water a quarter-, half- or full-circle area, and the area they cover depends on the pressure and volume of water that can be supplied to them and on the type of sprinkler.

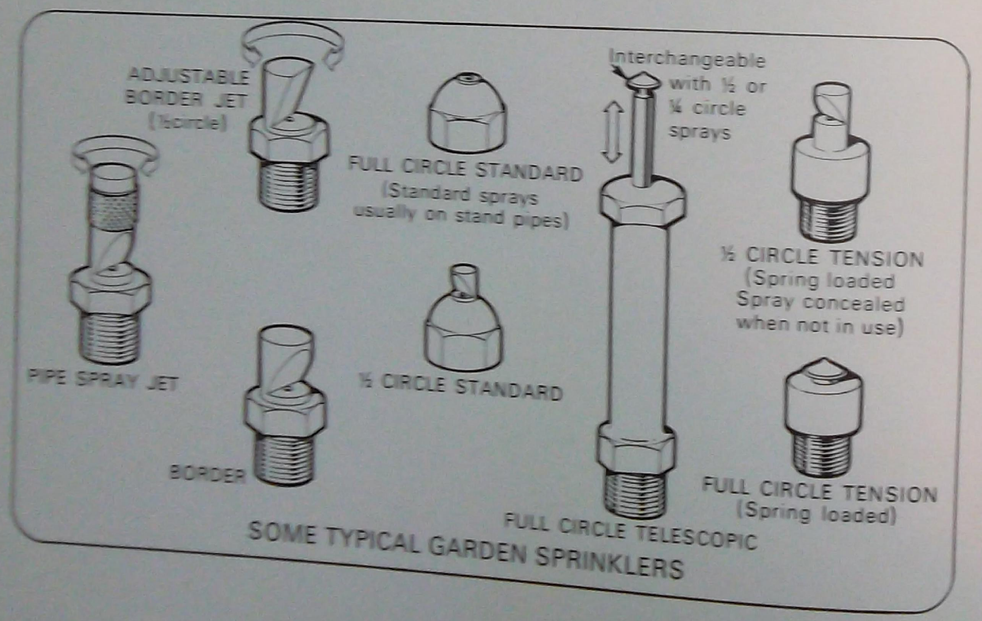
When considering the installation of such systems, it is advisable to consult manufacturers' catalogues and performance details to ensure satisfactory results are obtained.

Designing a sprinkling system requires careful planning to ensure:

- The whole area to be watered is covered.
- As little overlap as possible occurs.
- Small areas can be controlled by separate stop taps to avoid flooding and waste of water.
- Watering can be carried out in sections by installing stop taps in appropriate branches in case there is a reduction in water pressure or in the volume of water available.
- Stop taps are installed in accessible positions and out of range of the sprinklers.

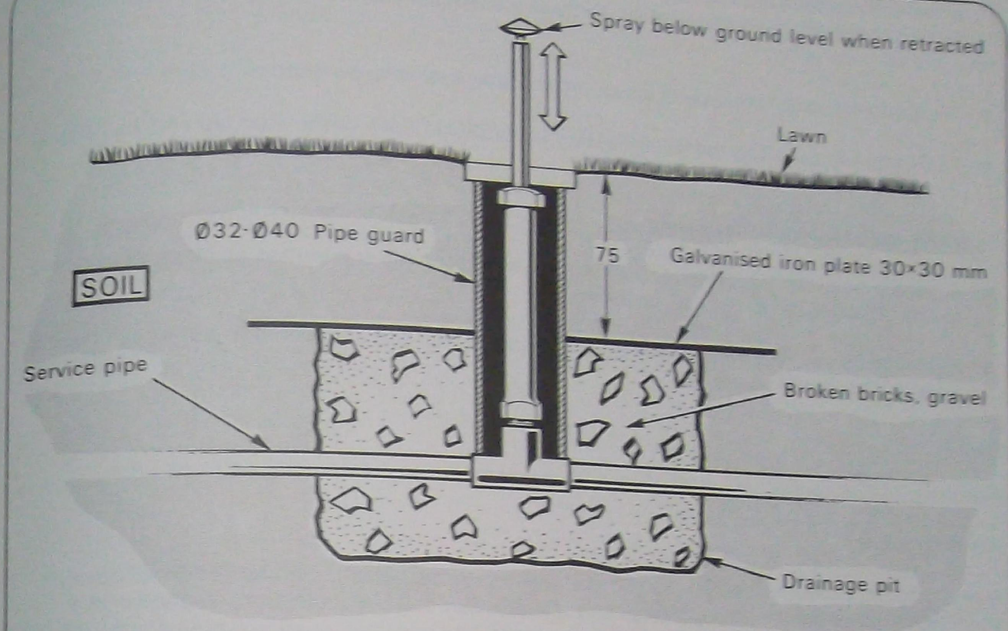
6.1 PLANNING THE SPRINKLER SYSTEM

The illustrations show a range of jets and sprays used in fixed sprinkler installations. Some border jets are fixed, others can be swivelled to adjust them to cover the required area more accurately.



SOME TYPICAL GARDEN SPRINKLERS

The arrangement of a typical telescopic sprinkler installation is shown.



TYPICAL FIXED SPRINKLER INSTALLATION WITH TELESCOPIC SPRAYS

The drainage pits, with broken bricks or rubble, are desirable but not strictly necessary around every sprinkler. In many cases it may be sufficient to have them on the lowest sprinkler or row of sprinklers for better drainage of excess water.

When installing such a system, bear in mind the following points:

- Never use hemp or jointing compound on any pipe joints beyond the control tap.
  - This may block the sprinklers. Small leaks in joints are of no consequence as there is only water in the pipes when the sprinkler system is turned on.
- Install a 32 or a 40 mm diameter pipe around the sprinkler, as shown.
  - This keeps the sprinkler free from dirt and makes it possible for a tubular spanner to be inserted for the removal or installation of a sprinkler assembly.

To connect each individual telescopic assembly, it is best to:

- Separate the inner tube from the outer.
- Install each outer tube to the branch pipe fitting.
- Flush out the whole system by turning the water on.
- Turn the water supply down to low and install the inner tubes, starting close to the trunk line and working outwards.

6.1.1 Spacing the sprinklers

To arrive at the most effective way in covering the area to be sprinkled, the correct and minimum number of sprinklers must be installed. To do this adequately and effectively, the plumber must take into consideration:

- The performance of the type of spray, jet or nozzle that is to be fitted.
- The water pressure and the water delivery available, not only at the stop tap end, but also at the end of the sprinkler network.

Sprinkler installations make use of:

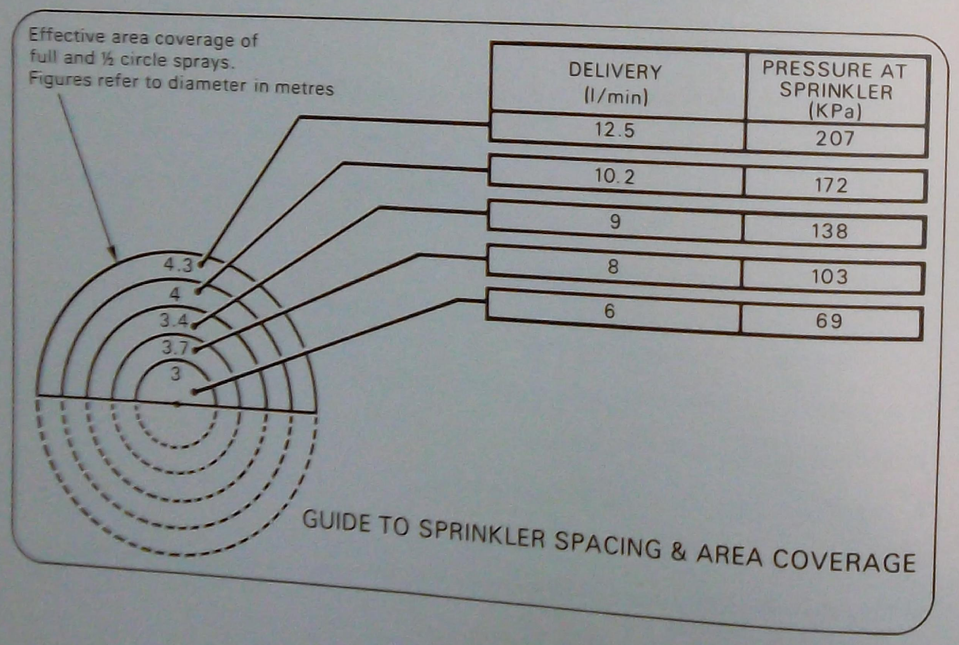
- A trunk pipe of 32 mm diameter between the main stop tap and ending as close as possible to the centre of the area to be sprinkled.
- 20 mm or 25 mm diameter branch pipes interconnected and connected to the trunk line at a number of suitable points.

NOTE:

Not more than 6 sprays are installed on a 20 mm branch pipe connected to a trunk pipe.

Area coverage

Manufacturers produce charts or diagrams, as shown below, which give the performance of sprinklers. These list the area coverage and rate of water delivery that can be expected at a specified water pressure. Such charts should always be consulted when planning a sprinkler system. They usually show the areas covered on the conservative side, allowances having been made for slight pressure losses during peak demands. The sprinklers spaced on this effective coverage pattern will normally give the necessary overlap of areas.



Pressure losses

Pressure losses due to friction in the pipe network must be taken into consideration when installing a sprinkler system. The smaller the pipe diameter, the greater the friction losses will be and the lesser the pressure and delivery rate will be at the sprinkler.

The tables below give the pressure losses due to friction in pipes of 20 and 25 mm.

PRESSURE LOSSES DUE TO FRICTION

20 mm DIAMETER PIPE	
CAPACITY (l/min)	PRESSURE LOSS PER 30 m (kPa)
9	7
18	28
27	61
36	110
45	173
55	251
64	328

25 mm DIAMETER PIPE	
CAPACITY (l/min)	PRESSURE LOSS PER 30 m (kPa)
23	10
27	15
36	25
45	41
55	60
68	86
91	152
114	231
136	328

The size of the pipe must be chosen carefully because of the sprinkler performance required, which in turn depends on the pressure available at the supply point and the length of piping installed.

Example calculation

Problem:

Four telescopic sprinklers of a type have to operate at 207 kPa at the end of a 60 m pipe. Calculate the most suitable pipe diameter for this installation if the available water pressure at the delivery point is 550 kPa.

Solution:

1. According to the chart (Guide to spacing and area coverage, page 62) operating at 207 kPa requires a delivery of 12.5 litres per minute per sprinkler or a total for that pipe of $4 \times 12.5 = 50$ litres/min.
2. The pressure loss table for the 20 mm pipe does not show the friction loss for the 50 l/min delivery; only the 45 and the 55 l/min losses which are 173 and 251 kPa respectively. The 50 l/min delivery lies between the 45 and 55 figures; in fact it is the average of the two. Similarly, we can expect the loss to be the average of the two figures also. Therefore, the friction loss for 50 l/min would be:

$$\frac{173 + 251}{2} = 212 \text{ kPa for a 30 metres length.}$$

3. But we have a 60 m length of pipe and, therefore, the pressure loss will be twice as high:

$$212 \times 2 = 424 \text{ kPa}$$

4. The pressure required at the sprinklers is 207 kPa and to compensate for the losses in the 60 m length of pipe, we therefore require at the supply point a pressure of:

$$424 + 207 = 631 \text{ kPa}$$

As we have only 550 kPa available, the 20 mm pipe is unsuitable.

5. With a 25 mm pipe our friction losses are:

$$\frac{41 + 60}{2} = 50.5 \text{ kPa per 30 m}$$

and for 60 m: $50.5 \times 2 = 101$ kPa

6. The pressure required at the delivery point should therefore be: $101 + 207 = 308$ kPa and, as we have 550 kPa available, the 25 mm pipe is quite satisfactory.

NOTES

Planning the layout

This must be done using the particular performance details for the make of sprinkler.

In this next section, we assume that a particular type of sprinkler, operating at maximum flow and pressure, covers an area of 4 m in diameter.

Now proceed as follows:

STEP 1

- Prepare a scale plan of the area to be watered.
- Divide the area with an even number of lines 2 metres apart (to scale of course) in one direction and 3.5 metres apart in the other, as shown.
  - This is the grid possible where maximum performance can be obtained. It may be necessary to reduce these dimensions to suit the area and the available water pressure.

STEP 2

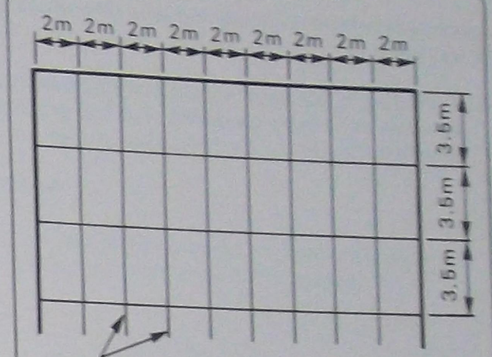
- Set compasses (to scale) at 2 m radius.
- Starting in one corner, draw circles with their centres located in a triangular pattern, as shown.

STEP 3

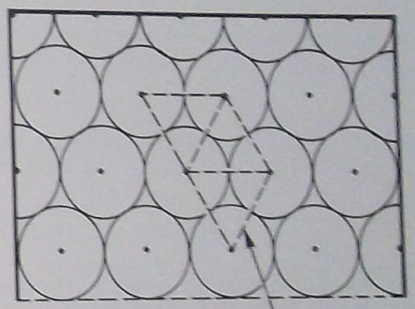
Bear in mind that each branch pipe laid can only support a certain maximum number of sprinklers adequately because of its diameter. The table below can be used as a general guide, although the manufacturers of various types of sprinklers will usually lay down such numbers for the various pipe materials, e.g. GS, plastic, UPVC.

It is sometimes advantageous to have a separate trunk pipe for each run. In such cases, the trunk pipe may be of smaller diameter.

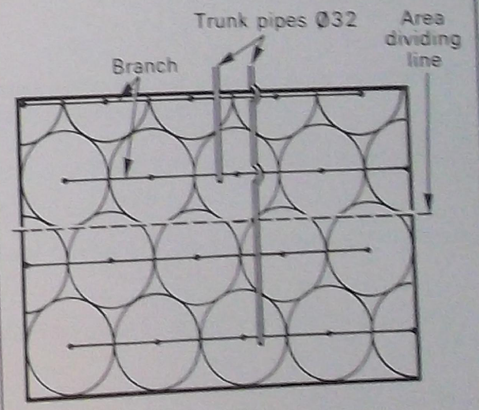
PIPE DIAMETER (mm)	MAX NO. OF SPRINKLERS
20	8
25	12
32	20
40	30
50	44



STEP 1–AREA DIVISION



STEP 2–PLOTTING THE SPRINKLERS



STEP 3–AREA DIVISION

SPRINKLER PLANNING SEQUENCE

NOTE:

Special permission is usually required from Water Supply Authorities for the laying of pipes 25 mm and over.

- According to the water supply available (which will determine the size of the area that each sprinkler can cover), divide the area into groups of sprinklers suitable for the area to be supplied.

NOTES

7 FIRE-PROTECTION SERVICES

The fire-protection services in buildings usually consist of two water systems, each separately connected to the mains. They are:

- The automatic fire sprinkler system.
- The network of standpipes with their hoses and control valves (for manual operation).

NOTE:

Where the fire risk is not considered high, the sprinkler system is sometimes replaced by a network of smoke- or heat-sensor devices electrically connected to an alarm system.

7.1 AUTOMATIC SPRINKLERS

These water sprinklers are designed to operate automatically in the event of fire and to hold the fire under control until the arrival of the fire brigade.

The piping system, usually in GS or in black steel pipe, is assembled and installed following the general principles of water supply installation and is attached to ceilings or floor members overhead. The individual sprinklers are fitted to this piping system and spaced so that they cover an area of between 6 to 8 m², depending on the type of building and the fire risk involved.

Sluice valves or gate valves are installed in the system for control between the main and the fire service line. These are located at the main itself or near the building at ground level and are easily accessible from the outside.

Gate valves, located at strategic points, are installed so that various branches of the system can be isolated for maintenance and adjustments when required.

7.1.1 Water supply to fire sprinklers

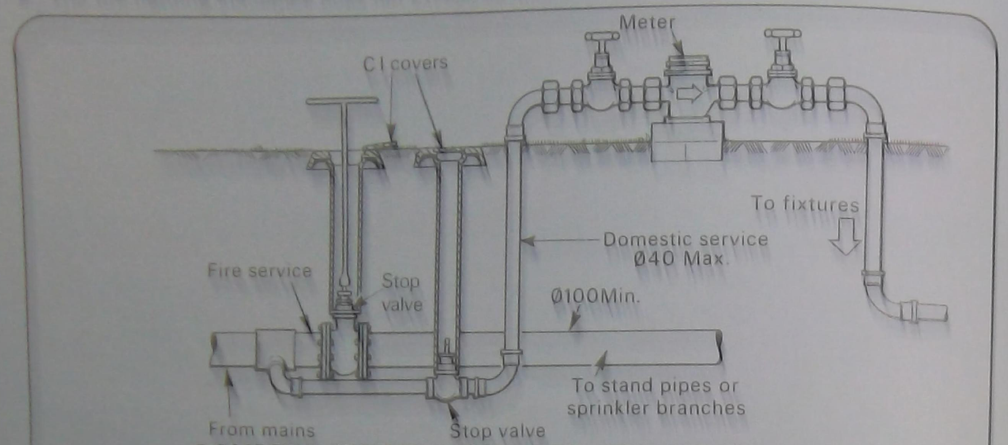
The fire sprinkler supply line (service pipe) is usually not less than 100 mm and the various branches to which the individual sprinklers are fitted are connected to it with standard fittings of the appropriate size.

The sprinkler system may be connected to a variety of water supply sources such as:

- Town's mains — usually.
  - If pressure is insufficient for proper operation, a booster pump may have to be provided. The pump starts automatically when a flow of water occurs in the system.
- Pump, electric or engine driven, drawing its supply from a practically unlimited supply such as a river, creek or dam.
- Elevated private reservoir, specially designed and installed for the purpose and which acts as a substitute for a town's mains.
- Elevated gravity supply tank or a pressure tank to be used as secondary sources of supply.

In certain circumstances, it may be permitted to tap the domestic service pipe or the fire-fighting standpipe into the sprinkler service pipe, provided:

- The sprinkler service pipe is not less than 100 mm.
- The domestic service is not more than 40 mm and is not used for industrial purposes.
- The fire-fighting standpipe does not exceed 50 mm.



DOMESTIC SERVICE TAPPED INTO FIRE SERVICE

The installation details illustrated above may vary from State to State.

7.1.2 Sprinkler design and operation

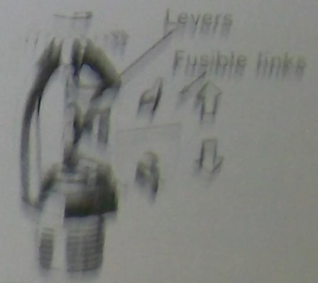
The illustration, page 69, shows some of the designs in automatic sprinkler valve arrangements. The spherical valve, often made of glass or stainless steel, is held on its seat by metal strips soldered together and supported by the frame. Should a fire occur, and the surroundings of the sprinkler head reach a predetermined temperature, the special solder will melt and the metal strips will fall apart. The water pressure will then force the valve off its seat and water will be sprayed over the area by the deflector which breaks up the water jet from the outlet.

Some designs make use of breakable glass bulbs in which the fusible element is a special fluid contained in the hermetically sealed bulb. The amount of fluid is accurately measured before it is poured into the bulb. When the bulb is sealed off, there remains a small vapour bubble which is visible under normal temperature. Should the temperature rise, the liquid expands and exercises pressure on the vapour bubble until it disappears and if the temperature continues to rise beyond that at which the sprinkler should operate, the pressure inside the bulb becomes so great that it shatters. The waterway then opens and the sprinkler comes into operation.

Sprinkler heads can be installed:

- Upright
- Pendent
- Along walls
- Recessed in ceilings


PENDENT TYPE



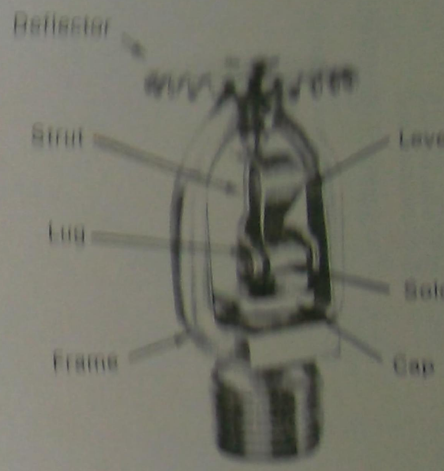
SOLDERED LINK & LEVER TYPE



SIDEWALL MOUNTING TYPE



GLASS BULB TYPE



UPRIGHT TYPE

OPERATION

SOLDERED LINK & LEVER

1–Eutectic solder melts

2–Links separate through lever pressure

3–Levers break away

4–Sprinkling starts

SOLDER IN COMPRESSION PRINCIPLE

1–Strut lugs exert pressure on stainless steel balls held captive in solder of capsule ends

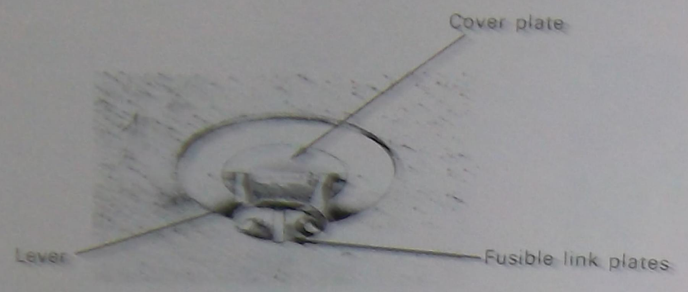
2–Solder melts

3–Balls pushed into capsule

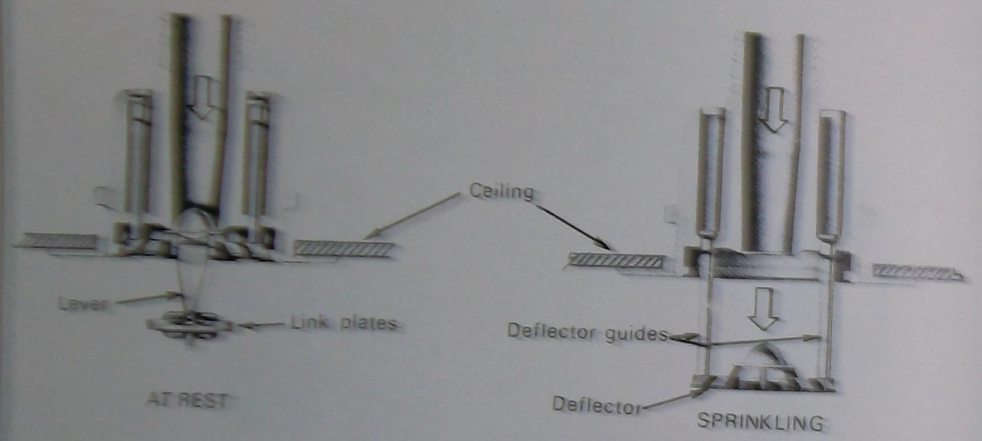
4–Capsule lever & strut fall away

5–Sprinkling starts

SOME AUTOMATIC SPRINKLER TYPES & THEIR OPERATION



SPRINKLER MOUNTED IN CEILING



RECESSED SPRINKLER

Depending on requirements, the sprinklers may be equipped with deflectors which allow a portion of the water discharge to be distributed against the ceiling and the rest downwards; others discharge only via the deflector.

Sprinkler heads come in various temperature settings, depending on the type of protection required. The range of settings can vary from as low as 57°C to as high as 182°C or even more and each rating is identified by a colour code.

Sprinkler heads can also be installed recessed into ceilings or flush with ceilings. With this type, only the fusible links and the lever mechanism are visible.

In the event of a fire, the fusible links melt, the levers are freed and allow water pressure to force the valve off its seat. At the same time, a retractable deflector is lowered, so allowing the sprinkling of the area to take place.

A sensing device is built into the system and connected to an alarm bell or a siren and it may activate an alarm signal connected directly to the fire brigade station. This will occur as soon as a flow of water is detected in the sprinkler piping network.

7.1.3 Standpipes (Hydrants)

Standpipes are located at strategic points and must be accessible at all times. They are painted red.

The end of the standpipe has a control valve attached to it and a suitable length of fire-hose fitted which in turn ends in a nozzle. These valves are sealed to prevent their use for any purpose other than fire fighting. The seal itself is easily broken when the valve needs to be opened in an emergency.

In most cases, the standpipe water service line is taken directly from the mains but it may also be combined with a sprinkler system and, provided the sprinkler service pipe is at least 100 mm and the standpipe service pipe does not exceed 50 mm, the latter may be tapped into it in a similar manner as detailed under Section 7.1.1.

REVISION QUESTIONS

1. a In designing a fixed garden sprinkling system what are the points to watch?

   b Give reasons why in installing a telescopic system:

   (i) No hemp should be used for joints beyond the control tap.

   (ii) There should be a pipe around the sprinkler assembly.

   c Describe the connecting procedure for the individual sprinkler to the branch pipe.

2. a What are the factors that determine the spacing of sprinklers? How are these factors obtained?

   b What is the name of the pipes used in a sprinkler layout and what are the usual sizes?

3. List and describe, in turn, the steps for the planning of a sprinkler layout. You may illustrate each step with the necessary diagrams.

4. a What are the two main fire-protection services provided for buildings?

   b To what water supply sources can the sprinkler system be connected? Discuss in some detail.

   c Under which circumstances is it permissible to tap the domestic service pipe or the fire-fighting standpipe into the sprinkler service pipe?

5. a List some of the sprinkler designs in use in automatic fire sprinkling systems and describe briefly their operation.

   b Describe briefly a standpipe set-up.

NOTES FOR THE INSTRUCTOR

In these Training Manuals the term 'instructor' refers to any person who may train or be directly responsible for training individuals.

For example, the task of instructing may be the sole or shared responsibility of:

—skilled tradesmen

—leading hands

—foremen

—instructors

—apprentice masters

—managers

INITIAL PLANNING

A Analyse:

- The training requirements of a newcomer, considering that the person:

  —may have no previous experience in the subject;

  —will need to do productive work as soon as possible.

- What the trainee must learn about:

  —the tools he is to use for the subject;

  —the terminology involved in the subject;

  —basic working methods.

- What will be the first productive work you will be able to give the trainee.

B Decide:

- Whether your trainees need information to supplement that given in this manual.
- Whether or when additional training material or exercises will be required to improve on the skill gained.
- Which other Basic Training Manuals the trainee should use during training.

C Plan:

The explanations, demonstrations and the practice required by the trainee, preferably on an individual basis, if numbers allow.

USING THE MANUAL

It may be of assistance to the trainee to arrange for short periods of learning followed by short periods of practice in applying the knowledge gained.

To keep interest alive, it will be useful to relate, as much as possible, the material treated in this manual with actual practical applications in the field.

PRACTICAL EXERCISES AND PROJECTS

There may be areas and tasks in actual situations where the developing skills of the trainee can be put to effective productive use at any stage during the period he is learning the subject. Such possibility should be carefully considered and used to the full for the trainee's benefit as well as that of the firm.

Give the trainee as many opportunities as possible to use the whole range of hand tools on suitable small jobs to enable him to acquire quickly the manual dexterity required.

Small projects and exercises to suit particular work situations may be devised, but they must take into consideration the limits of skill and knowledge of the trainee.

Whatever form of exercise is used to develop practical skill, it must be carefully planned. A suggested course of instruction is:

- Prepare the working area, the materials and the hand tools to be used.
- Make the aim of the project clear to the trainee.
- State how you intend to assess the proficiency of the trainee.
- Stress key points in the project, paying particular attention to safety precautions.
- Explain clearly and thoroughly any new steps in the project.
- Check that the trainee can use the hand tools correctly.
- Assess the finished project, record the results and discuss with the trainee your appraisal of his performance.
- If you are satisfied with his performance, direct the trainee to the next exercise or project.

TRAINING RECORDS

Simple training records will help in planning systematic training.

Record:

- the parts of the manual learnt by the trainee;
- your assessment of the general skills developed;
- the practical exercises undertaken and completed.

Use your record to measure the trainee's performance and to assess his readiness for undertaking actual operations.

Draw up a simple record card to suit your needs.

Using records helps to pinpoint the trainee's strengths and weaknesses. They ensure that training in essential skills is not missed. Training records can be used to help co-ordinate on-the-job training and technical school learning. Where trainees have to serve a probationary period, records assist when the trainee's progress is being assessed.

PUBLICATIONS IN BASIC TRAINING MANUALS — WATER SUPPLY

Title	
11.1	WATER SUPPLY — 1
11.2	WATER SUPPLY — 2
11.3	WATER SUPPLY — 3
11.4	HOT-WATER SYSTEMS

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BASIC TRAINING MANUAL

11-1

Water Supply 1

NATIONAL BUILDING AND CONSTRUCTION
INDUSTRY TRAINING COUNCIL

DEPARTMENT OF EMPLOYMENT, EDUCATION AND TRAINING

BASIC TRAINING MANUAL

11-1
Water Supply 1

Australian Government Publishing Service
Canberra

This manual has been produced as the result of the need to update existing manuals in line with the revised National Plumbing Code and to have comprehensive manuals on the aspects of plumbing available for trainees in the trade.

The topics of this manual were compiled by Mr. R. Verity of RMIT in consultation with a working panel appointed by the National Building and Construction Industry Training Council who have approved this publication on behalf of the National Training Council.

The panel consisted of:

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The manual was prepared by the Training Manuals Unit of the Department of Employment, Education and Training.

This advice and valuable contributions given to the successful production of this publication by the panel are gratefully acknowledged.

EDITOR: Mr. J. R. M. Jentzema.

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First printing 1979
Revised edition 1983
Reprinted 1988

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ISBN 0 644 00499 1

Printed by Ambassador Press Pty Ltd, 51 Good Street, Granville, NSW 2142

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PREFACE

This manual forms part of a series on basic plumbing skills, specifically designed as practical training aids for apprentices in this trade.

It is based on a general syllabus content that exists for courses in the plumbing trades.

Each manual is self-contained and is intended as an instructional guide in on- or off-the-job training situations. It may be used by instructors, or by trainees for self-teaching and private study purposes.

The aim of the manual is to help the trainee to develop a particular skill to the stage where it can be applied productively on the job.

Ideally the manual should be used as part of a course of instruction involving:

- demonstrations of practical skills by instructors, experienced tradespeople or operators;
- planned and supervised practice in handling the tools or machines involved;
- instruction in related theory and workshop technology.

Some notes for the instructor to assist in planning systematic training on the job are included.

The manuals, or the topics they cover, may be used in any order convenient to the learning needs of the trainee.

As much as was possible to ascertain, most of the important fields have been covered. In special circumstances, it is expected that instructors and trainers will provide trainees with the specific additional information to comply with any local conditions which are at variance with the contents of this manual, where this may be the case.

USER COMMENT SHEET

Please use the sheet on page 135 to let the Training Publications Unit know your assessment of the quality of the material contained in the manual and what future training material should be produced.

INSTRUCTIONS TO TRAINEE

This manual is a teaching aid to help you develop skills you need in your job. It is based on the job where you can handle the tools and use the equipment.

You should follow the directions given by the person training you. To reach the required standard of skill, you must pay particular attention to your instructors' explanations and demonstrations. Supervised and individual practice is essential.

Practice means making repeated efforts to improve your level of skill. Study is making an effort to learn. Every advance in skill depends on study and practice. You will make most progress by co-operating actively in the training arranged for you.

When you are told to study all or part of this manual, try and use a definite plan of study. The following plan is effective.

SURVEY: Read quickly through the headings as you turn the pages. Glance at the drawings. Get an overall view before you read.

QUESTION: Ask yourself: What do I know? What do I need to know? How will this manual help me to learn?

READ: Read right through each section carefully. Be thorough, but do not dawdle. Reading quickly will help you concentrate.

DO: Use all your senses in learning. Getting the 'feel' of any tool of equipment is essential in learning to use it. Follow the directions given to you.

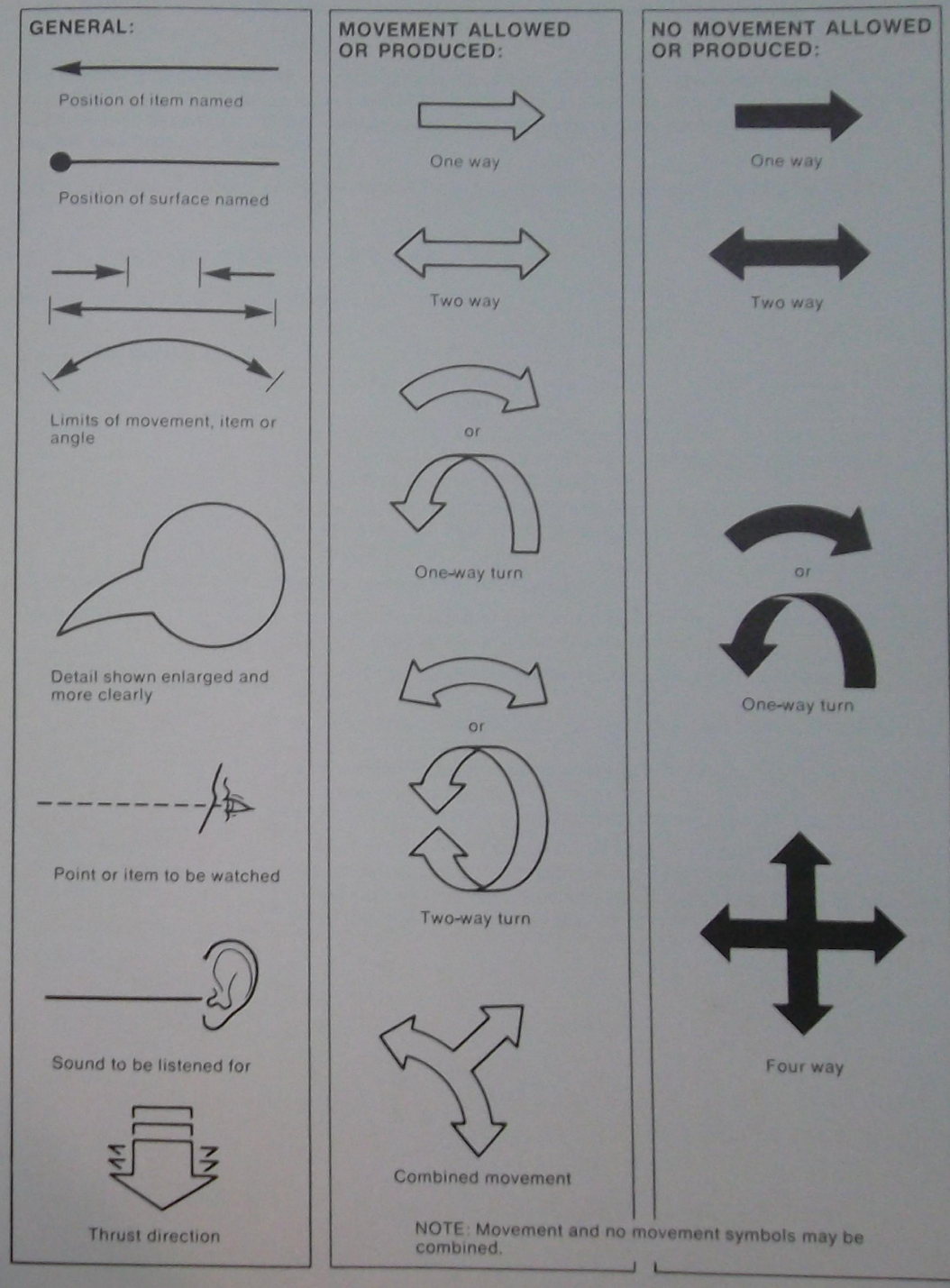
REVIEW: Shut the manual. Try to remember the main points of the section. Check to make sure that you are right. Revise points on which you are doubtful; often if necessary.

One way of fixing important instructions in your mind is to repeat them over and over.

Careful study of and practice in the various trade skills treated in this manual will help you develop them to work safely and productively.

SYMBOLS

The symbols shown are used in illustrations in these manuals.



1 INTRODUCTION

This manual is the first one in a series of four dealing with the specific requirements of modern-day plumbing as it applies to the supply of water to properties in general and to some more specialised cases that can be met in the installation of water supply systems for industry, hospitals and the like.

The plumber's responsibility for connecting the water supply extends from the Water Supply Authority's mains to the fixture to be served. The installation of such a service must be carried out at all times in an expert and efficient manner, using approved materials and be in accordance with the current standards and regulations.

Some of the main general points to remember and which apply to any water supply installation are:

- The water supply requirements of fixtures.
- The avoidance of cross connections.

2 TERMINOLOGY

TERM	DEFINITION
Air gap	The unobstructed vertical distance through the free atmosphere between the lowest outlet of a pipe or fitting discharging fluid to a tank, fixture or other device; and ● the spill level of the receptacle for those with piped overflows; or ● the overflow level of the receptacle for those without piped overflows.
Approved	Means approved by the Authority.
Authority	The Authority which is authorised by statute to exercise jurisdiction over the installation of water supply plumbing.
Capacity	The capacity of a water heater or container must be one of the following: ● For electric storage water heaters: the rated hot water delivery in litres. ● For other storage water heaters or containers: the nominal storage capacity in litres. ● For heat exchange water heaters: the storage volume in litres.
Check valve (Non-return valve or reflux valve)	A valve which prevents reversal of flow in the pipes of a water supply system by means of the check mechanism, the valve being opened by the flow of fluid and closed by the action of the check mechanism when the flow ceases, or by back pressure.

TERM	DEFINITION
Cistern-fed water heater	A water heater supplied with cold water from a feed tank in which the level of the water is automatically maintained. The cold water feed tank may form an integral part of the water heater or it may be detached and mounted separately in such a manner that the maximum working head is not exceeded.
Container	The vessel in which the heated water is stored. (Sometimes referred to as the storage container, cylinder or tank.)
Combination relief valve	A valve which incorporates the features of temperature and pressure relief valves.
Displacement water heater	A water heater in which cold water is fed into the container at or near the bottom, displacing the hot water but not mixing with it as it is drawn off at, or near the top.
Domestic type	A fixture or appliance designed for residential use. A fixture or appliance of this type may be installed in a non-residential building, but the sewage which it discharges must be similar to that which would be discharged if installed in a residence.
Expansion relief valve	A pressure-actuated valve which automatically discharges fluid during the normal heating cycle of the hot water system.
Falling level water heater	A water heater with a free-water surface, from which hot water is drawn off at or near the bottom, the level of the water falling as the hot water is drawn off.
Fittings	Means apparatus or devices for installation in the water supply system hot water service or fire service of any property and includes any tee, reducer, elbow, bend, valve, fire hydrant and fire hose reels, but does not include any fixture or straight piping.
Fixture	Means any receptacle, apparatus or device forming part of the water supply system or hot water service of any property, which is supplied with water and/or which receives liquid or liquid-borne wastes that are intended to be discharged directly or indirectly to the sewerage system; it includes any trap installed as a floorwaste gully, and any water closet pan, bath, basin, sink, shower, wash trough or cistern and the like, but does not include water heating apparatus or water storage tanks, or any vats, or similar processing equipment.
Float valve	A valve operated by a float and designed to maintain a constant level of water in a feed tank. It is sometimes called a ball valve or ball cock.

TERM	DEFINITION
Flood level rim	The lowest part of the top edge of any fixture from which water will overflow.
Free-outlet water heater	A water heater with a permanently open outlet from which hot water is discharged by displacement, the flow of water being controlled by means of a valve or tap in the inlet water feed pipe.
Gate valve	A valve which provides a straight-through passage for the flow of fluid. The body ends are in line and the gate is moved between the body seats by a stem whose axis is at right angles to the line between the body ends.
Heat-exchange water heater	A water heater in which cold water is fed into a heat-exchanger (e.g. a coiled tube or similar device) which is immersed in a container of static heated water or other suitable medium.
Hot water service	All parts of the installation and all equipment and materials necessary to provide an efficient supply of hot water at the specified outlets.
Instantaneous water heater	A water heater in which the heat energy is applied only while water flows to the outlet(s).
Isolating valve	Any valve installed for the purpose of shutting off part of a water supply system from the remainder.
Mains pressure water heater	A water heater, hydrostatically tested to a minimum of 2000 kPa, which is connected directly to the cold water mains in such a manner that hot water is delivered at the cold water mains pressure.
Maximum head	The maximum water pressure to which a water heater is to be subjected, expressed in metres of water head (or kPa for unvented water heaters), as measured at the lowest point of water heater.
Nominal size	The size of pipe and fittings in accordance with the relevant Australian Standard.
Non-return valve	See check valve.
Pipework	The assembly of pipes and fittings.
Plug tap	A device used to regulate or stop the flow of a fluid by the rotation of a drilled or slotted plug in its seating.
Potable water	Any water which does not contain any matter, pollution, contamination or minerals of an objectionable nature or in excessive quantity, or any infectious material and which is considered by the Authority to be satisfactory for human consumption, culinary and domestic purposes.

TERM	DEFINITION
Pressure-limiting valve	A valve which limits its outlet pressure to within specified limits of the set pressure, when the inlet pressure rises above the set pressure.
Pressure-ratio valve	A valve which automatically reduces outlet water pressure to a specified ratio of its inlet pressure.
Pressure-reducing valve	A valve which automatically reduces inlet water pressure to a specified value at its outlet.
Pressure-relief valve	A pressure-actuated valve which automatically discharges fluid at a specified set pressure.
Pressure water heater	A water heater having a maximum working pressure greater than 21 kPa (maximum working head greater than 2 m) but less than that of mains pressure. This includes both vented and unvented water heaters.
Primary circuit flow and return pipes	Pipes which respectively convey water from the source of heat to the container and from the container back to the source of heat.
Reflux valve	See check valve.
Secondary circuit flow and return pipes	Pipes which respectively convey hot water from and return it to the container and from which hot water may be drawn.
Side-fed water heater	A displacement type of water heater with a free water surface in which the cold water is supplied from an integral feed tank attached to the side of the heater. The hot water is drawn off at an outlet located below the free water surface.
Spill level	For any fixture, storage tank or receptacle it is the maximum height to which water will rise while overflowing freely, either over its rim or through any channels or overflows that are provided and have a free discharge to the atmosphere under all conditions when water is flowing into such fixture, storage tank or receptacle at the maximum rate, under a pressure equal to a head of 70 m, applied either at the outlet end of the pipe or at the inlet to the fitting or valve actually discharging such water, while all the service outlets of such fixture, storage tank or receptacle are closed.
Stop tap	A screw-down pattern tap with a loose jumper valve, and with the inlet and outlet both having suitable means for connection into a pipeline.
Storage water heater	A water heater incorporating a thermally insulated container in which the water is heated and stored for subsequent use.
Temperature-relief valve	A temperature-actuated valve which automatically discharges fluid at a specified temperature.

TERM	DEFINITION
Unvented water heater	A water heater without provision for a vent, permanently open to the atmosphere.
Vacuum-relief valve	A valve which automatically opens to relieve vacuum conditions.
Valve	A device for controlling the flow of a fluid.
Vent or exhaust pipe	An open-ended pipe connected at any high point in a hot water system, or from any vessel containing hot water, so arranged that the open end discharges into the air space of the cold water storage tank or to the outer atmosphere.
Watermain	Means a conduit or pipeline for which the Authority is responsible.
Water heater	An appliance, usually self-contained, for heating water which is either stored in it or passing through it.
Water service	The pipes and fittings used, or intended to be used, for the supply of water to a property from the watermain up to and including the meter assembly, if required.
Water supply system	The pipes and fittings used, or intended to be used, for the supply of water from a meter assembly to the points of usage within any property and includes any water storage tank or pipes therefrom.

3 WATER SUPPLY TO FIXTURES

- No water service pipe may be laid or connected for the supply of water from the mains to any fixture unless the Supply Authority has given permission in writing for such a pipe to be laid and connected.
- Pipework must be such a size that it it will deliver between 6-10 litres per minute to any fixture, flushing cistern, flushing tank or other flushing device.
  - — The Supply Authority may well lay down the requirement in local regulations.
- When used in any fixture, the water as supplied from the mains of the Supply Authority or from another approved source must discharge to that fixture through an air gap of at least 20 mm. (See Table page 8.)

3.1 AVOIDANCE OF CROSS CONNECTIONS AND BACKFLOW

The pipework for the supply of water to any fixture may be connected directly to it or indirectly through storage tanks or flushing cisterns. For obvious health reasons, such pipework must be so connected that the contents of any fixture, storage tank or flushing cistern cannot flow back into the water supply system.

3.2 TERMINOLOGY

TERM	DEFINITION
Backflow	The unwanted reversal of flow of liquids in a piping system.
Back pressure	Occurs when the pressure within a container, receptacle or pipework system is higher than the pressure within the water service pipework. Back pressure may be caused by either a pressure increase within a container or receptacle, generated by an external energy source, or by a drop of pressure within the supply pipework.
Back syphonage	Occurs when the pressure within the water service pipework falls below atmospheric pressure.
Contaminant	Any substance not intended to be present within a potable (drinkable) water supply. For the purpose of this book, contaminants are classified into three degrees of hazard: • Bacteriological — When any substance is present that contains bacteria that might be detrimental to health, if consumed. • Toxic — When any substance of a chemical nature is present which might be detrimental to health, if consumed. • Non-Toxic — When any substance is present which would not normally have any detrimental physical effects, if consumed.
Cross connection	Any actual or potential connection between a potable water service and a source of contamination or pollution. Cross connections are generally one of two types: • Inlet type — The potable water supply pipework extends above the spill level of the receptacle, or in the case of garden sprinkler systems, and the like, above the water supply outlets which might constitute the cross connection. With these types of cross connections, backflow can only occur due to back syphonage. • Direct or pressure type — The potable supply pipework is at, or below, the spill level of the receptacle or the water supply outlets which might constitute the cross connection, or where the water service may become pressurised by a malfunction in a boiler or pump installation. With these types of cross connections, backflow may occur due to back syphonage or back pressure.

3.3 TYPICAL CONTAMINANT HAZARDS

The contaminant hazards shown in the table below are meant as a guide only; the final decision with respect to the actual hazard rests with the Approved Authority.

TABLE OF CONTAMINATION HAZARDS

INSTALLATION	CONTAMINANT HAZARD
Pumps, tanks, pipework and fixtures connected to a sewerage system, including flush valves.	Bacteriological
Fire services	
• With fire brigade pump connections.	Non-toxic
• Storage tanks.	Non-toxic
• Treated for scale, or algae formation, or containing antifreeze.	Toxic
• With black iron pipes.	Non-toxic
Garden and agricultural watering systems	
• With water outlets less than 150 mm above ground level.	Non-toxic
• With fertiliser or insecticide injection.	Toxic
Steam Boiler	
• With rust and scale inhibitors.	Toxic
• Without rust and scale inhibitors.	Non-toxic
Drink dispensing equipment, beverage vending machines, soda fountains, etc.	Non-toxic
Potable water treatment equipment, filters, water softeners, chlorinators, etc.	Non-toxic
Central heating systems with pipework not complying with chapter 8 of the National Code.	Non-toxic
Commercial and manufacturing installations	
• Car wash installation.	Toxic
• Coils and jackets in heat-exchangers.	Toxic
• Tanks, vats and vessels used for plating, degreasing, descaling, stripping, pickling, clipping, etc.	Toxic
• Tanks, vats and vessels used for preparation or storage of food.	Non-toxic

3.4 QUALITY OF WATER SUPPLY

Only potable water is allowed to enter plumbing fixtures supplying water for drinking, bathing, culinary use or for the processing of food, medical or pharmaceutical products. The water downstream of a backflow prevention device must be considered non-potable.

3.4.1 General requirements

- Potable water supply systems must be designed, installed and maintained in such a manner that non-potable liquids, solids or gases are prevented from being introduced into the potable water supply through cross connections or any other piping connections to the systems.
- Backflow prevention devices must be selected in accordance with Table page 8 on the basis of hazard generated by the potential contaminant and the installation requirements.

TABLE OF PERMISSIBLE METHODS OF BACKFLOW PREVENTION

Type of backflow prevention device	Contaminant hazard P = permissible method of backflow prevention					
	Bacteriological		Toxic		Non-Toxic	
	System Subject to Back Pressure	System Subject to Back Syphonage	System Subject to Back Pressure	System Subject to Back Syphonage	System Subject to Back Pressure	System Subject to Back Syphonage
Air gap	P	P	P	P	P	P
Reduced pressure zone device	—	—	P	P	P	P
Double check valve	—	—	—	—	P	P
Pressure-type vacuum breaker	—	—	—	P	—	P
Atmospheric vacuum	—	—	—	P (See Note)	—	P
Barometric loop	—	—	—	P	—	P

NOTE:

Not to be used for permanent connections. May only be used where approved.

3.4.2 Air gap

The minimum air gap must be as set out below:

MINIMUM AIR GAP

Effective size of water supply inlet	Minimum air gap
Not more than 10 mm	20 mm
Not more than 15 mm	40 mm
Not more than 20 mm	60 mm
Above 20 mm	3 times the effective size of the water supply inlet up to 150 mm

3.4.3. Reduced pressure zone device

Reduced pressure zone device backflow prevention assemblies must be made from approved fittings for the particular application and must incorporate the following:

- Two independently acting spring-loaded check valves.
- A vented and drained spring-loaded pressure differential relief valve located between the check valves.

- Provision for testing the installation against malfunction.
- Isolating valves, installed upstream of the first check valve and downstream of the second check valve.
- A line strainer installed upstream of the upstream isolating valve required above.

Reduced pressure zone device backflow prevention assemblies must be inspected and tested in accordance with the requirements of the Authority, after installation and before being put into service, and thereafter at no more than yearly intervals.

Reduced pressure zone device backflow prevention assemblies must be installed such that:

- ready access is provided for inspection and servicing;
- the assembly is protected from freezing;
- the relief valve vent is given free ventilation to the atmosphere at all times;
- the relief valve drain discharges through an air gap and does not cause damage or nuisance.

3.4.4 Double check valves

Double check valve backflow prevention assemblies must be made from approved fittings for the particular application and must incorporate the following:

- two independently acting spring-loaded check valves;
- provisions for testing and installation against malfunction;
- isolating valves, installed upstream of the first check valve and downstream of the second check valve;
- a line strainer installed upstream of the upstream isolating valve required above.

Double check valve backflow prevention assemblies must be inspected and tested in accordance with the requirements of the Authority, after installation and before being put into service, and thereafter at no more than yearly intervals.

Double check valve backflow prevention assemblies must be installed in such a way that:

- ready access is provided for inspection and servicing; and
- the assembly is protected from freezing.

3.4.5 Pressure-type vacuum breaker

Pressure-type vacuum breaker backflow prevention assemblies must be made from approved fittings for the particular application and must incorporate the following:

- A positive acting spring-loaded ventilation valve.
- At least one positive acting spring-loaded check valve.
- Provision for testing the installation against malfunction.
- Isolating valves installed immediately upstream and downstream of the vacuum breaker fitting.

Pressure-type vacuum breaker backflow prevention assemblies must be inspected and tested in accordance with the requirements of the Authority, after installation and before being put into service, and thereafter at no more than yearly intervals. Pressure-type vacuum breaker backflow prevention assemblies are only effective against back syphonage and must be installed in such a way that:

- ready access is provided for inspection and servicing;
- the level of the vacuum breaker is not less than 300 mm above the spill levels of all receptacles, storage tanks, fixtures, etc., served or above all water supply outlets served; and
- the vacuum breaker vent is given free ventilation to the atmosphere at all times.

3.4.6 Atmospheric vacuum breaker

Atmospheric vacuum breaker backflow prevention devices must be made from approved fittings for the particular application. They are only effective against back syphonage and must be installed in such a way that:

- ready access is provided for inspection and servicing;
- the level of the vacuum breaker is not less than 300 mm above the spill levels of all receptacles, storage tanks, fixtures, etc., served or above all water supply outlets served;
- no valves are installed in the water service pipework downstream of the vacuum breaker;
- the vacuum breaker does not, under normal operation, remain continuously pressurised with water for more than 12 hours; and
- the vacuum breaker vent is given free ventilation to the atmosphere at all times.

3.4.7 Barometric loop

Barometric loops may only be used where approved.

- A barometric loop must be formed by looping the water supply pipework a minimum of 11 metres above the spill levels of all receptacles, storage tanks, fixtures, etc., served or above all water supply outlets served.
- A suitably designed air-water separator must be installed at the base of the downstream leg of the loop. The air-water separator must be vented through a minimum 15 mm pipe to the top of the downstream leg.

Identification of potable and non-potable water

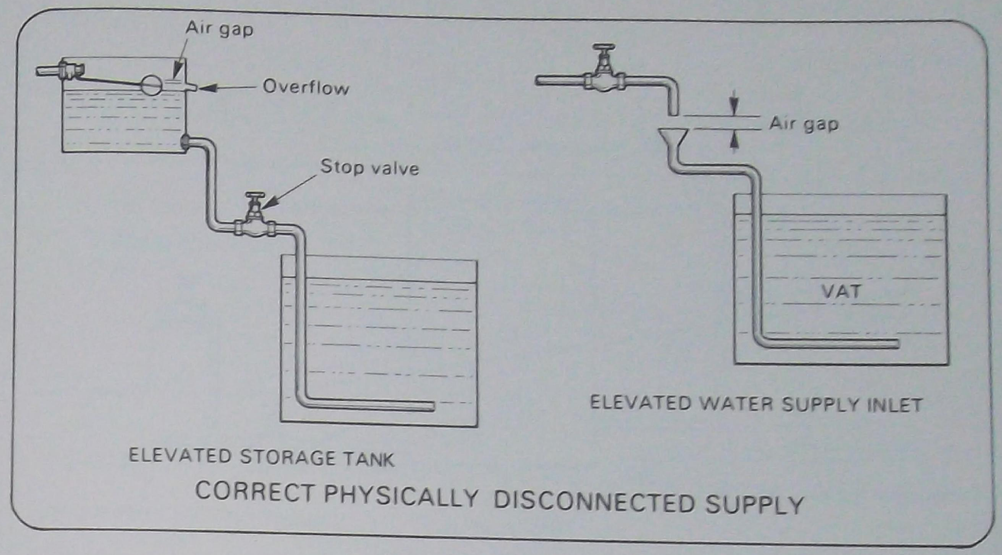
Where dual water distribution systems are installed, one with potable water and the other with non-potable water, each system must be identified by colour marking, metal tags or other approved method.

Protection of public water supply

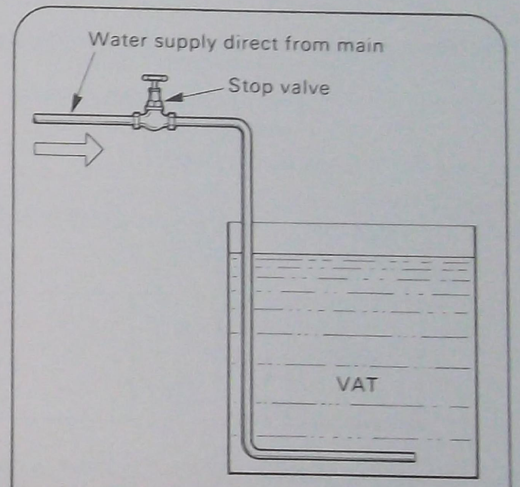
In commercial and industrial situations, the Authority may require the installation of a backflow prevention device on the property water supply system, located adjacent to the meter.

3.4.8 Correct and incorrect connections

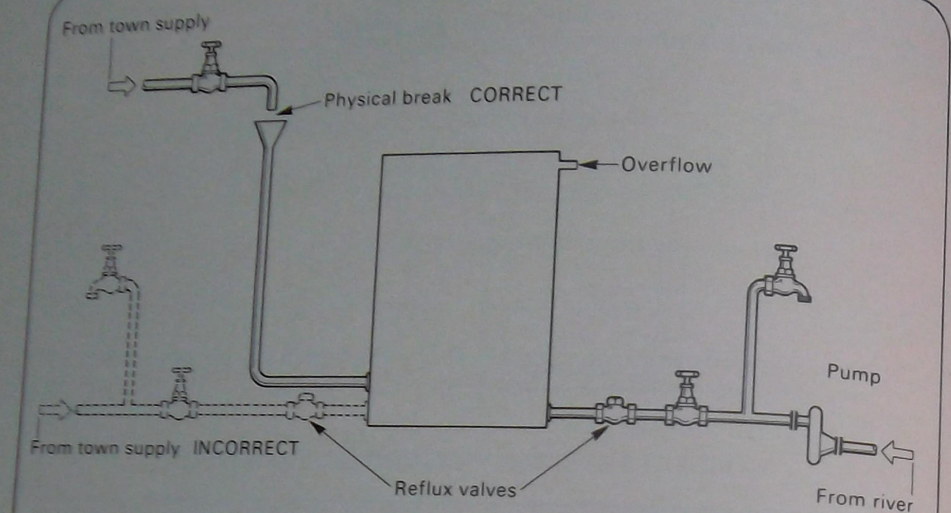
The illustrations on the following pages show a variety of applications designed to prevent backflow into the supply system. Study them carefully.



CORRECT PHYSICALLY DISCONNECTED SUPPLY



INCORRECT CONNECTION MAY CAUSE BACKFLOW BY SYPHONING



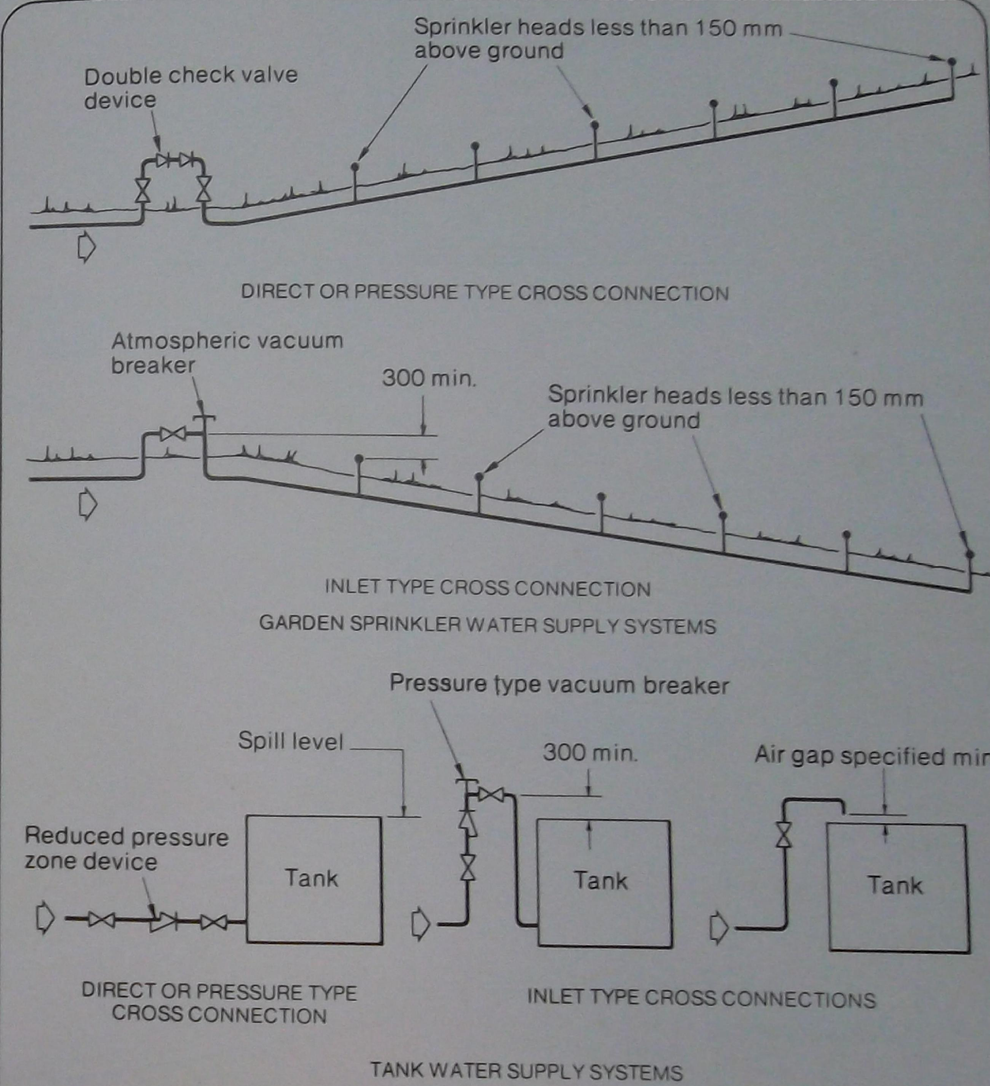
CONNECTION OF TWO DIFFERENT SUPPLY SOURCES

NOTE:

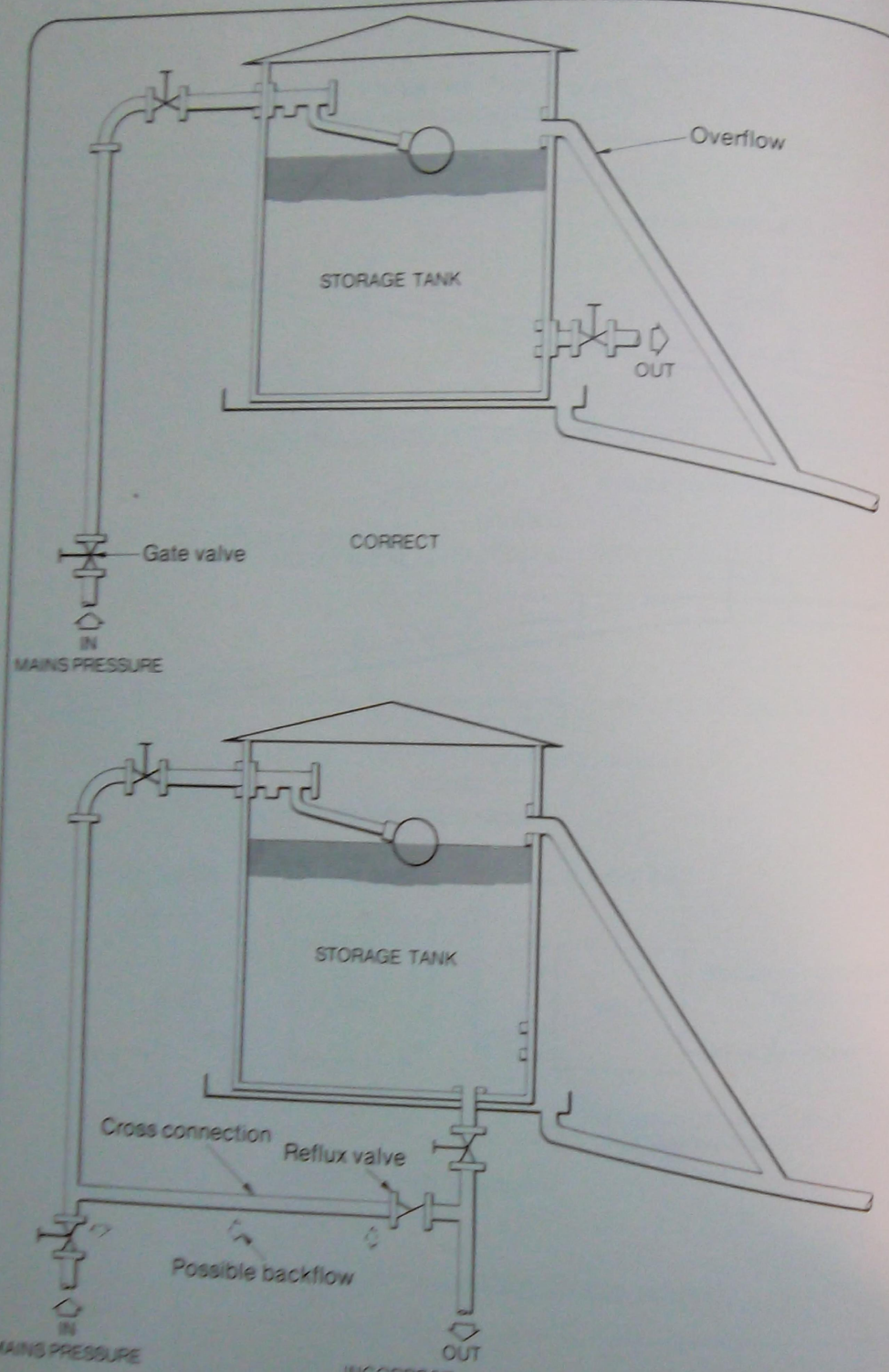
The incorrect method shown above may be approved under the National Code if the hazard is non-bacteriological.

NOTES

Back Flow on: 656m Devices:



TYPICAL USE OF BACKFLOW PREVENTION DEVICES



CROSS CONNECTION AT STORAGE TANK

CORRECT AND INCORRECT STORAGE TANK CONNECTION

Hairdressers' sprays

Correct and incorrect methods of installing hairdressers' sprays are shown. The incorrect method could result in polluted liquid being back syphoned into the service from the basin.

Bubble taps

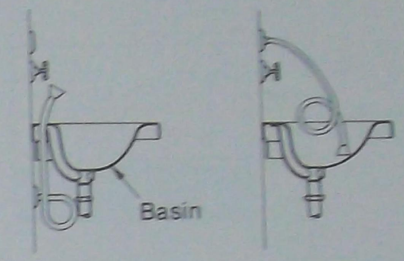
Correct and incorrect fitting of bubble taps are shown. It is preferable to have the whole of the piping and the bubbler outside the bowl, but there would be no objection to the water piping being brought up through the bowl, provided that no pipe joint is made inside the bowl because the purity of the drinking water could be affected by backflow should the outlet of the bowl become blocked at a time when there was a leak in the joint.

Basins

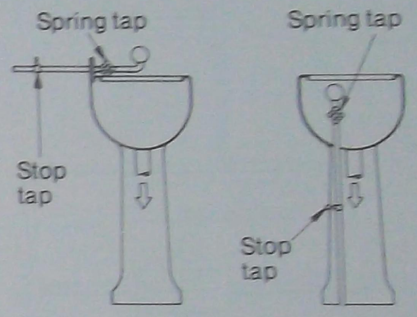
The correct and incorrect methods of fixing bib taps on basins are shown.

The bib tap should be above the spill level of the basin (see correct method). This requirement is defeated if the level of the basin on which the pillar tap rests is more than the required distance below the spill level.

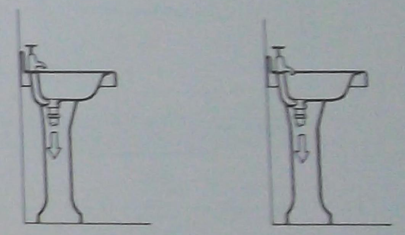
NOTES



HAIRDRESSERS' SPRAYS



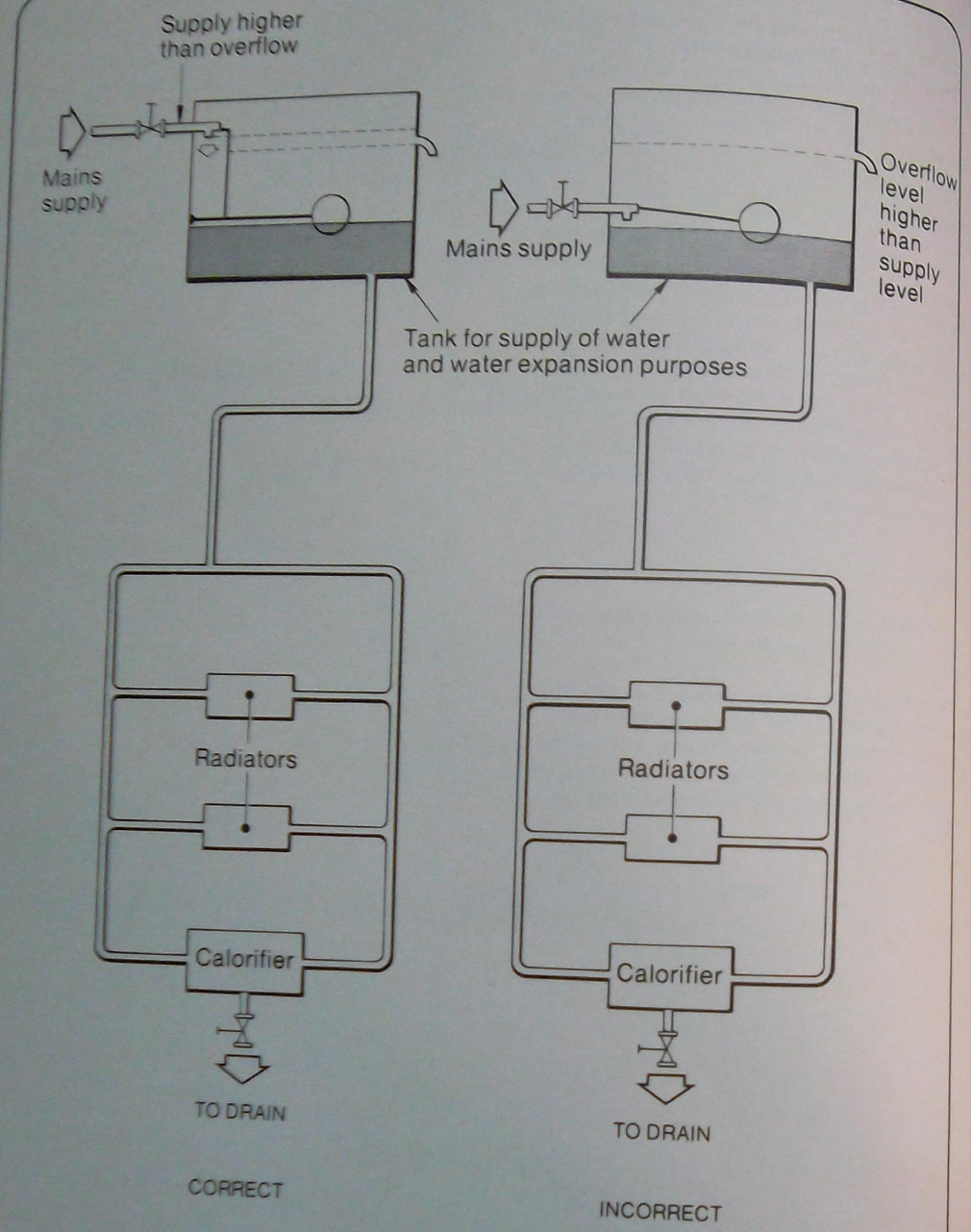
BUBBLE TAPS



BASINS

CORRECT INCORRECT

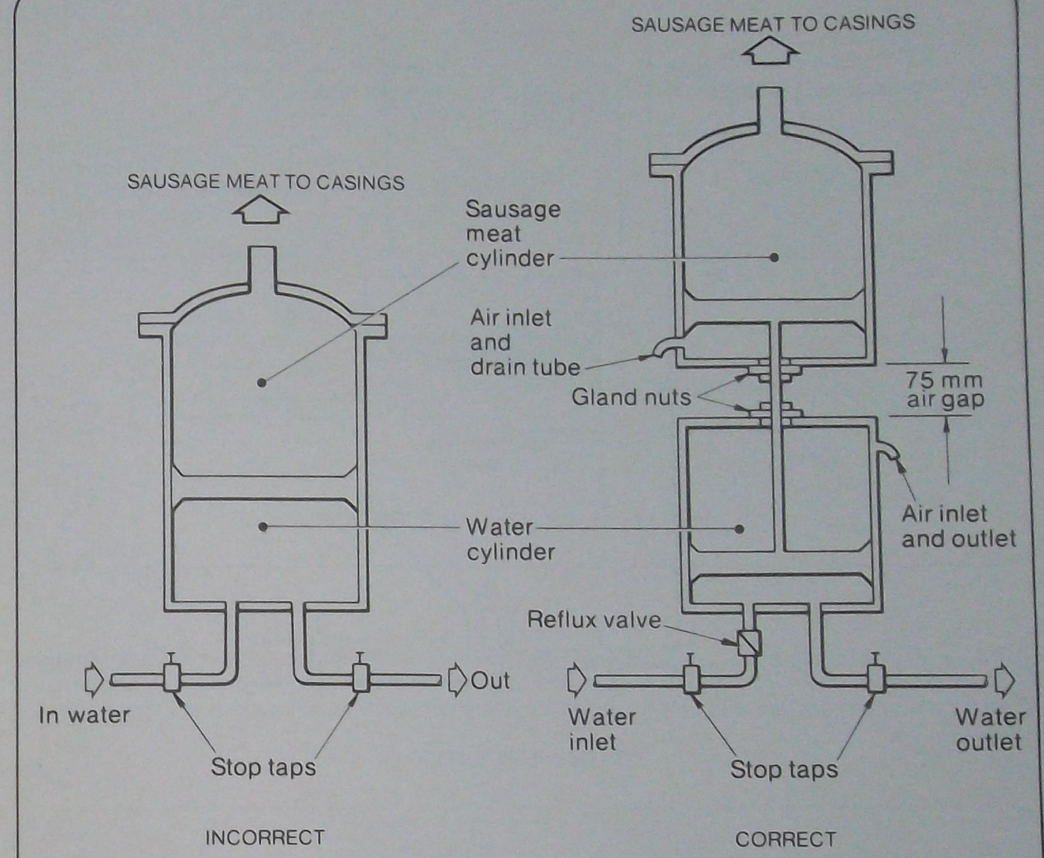
BACKFLOW IN DOMESTIC FITTINGS



CORRECT AND INCORRECT METHODS OF SUPPLYING WATER TO A HOT WATER RADIATION SYSTEM

Hot water radiation system

Correct and incorrect methods of supplying water to such an installation are shown. Provision is made in the storage tank for expansion of the water in the system and when this takes place, the ball cock is not submerged in the correct set up. The incorrect set up is not permitted.



PREVENTION OF BACKFLOW IN SAUSAGE MAKING MACHINES

Sausage making machines

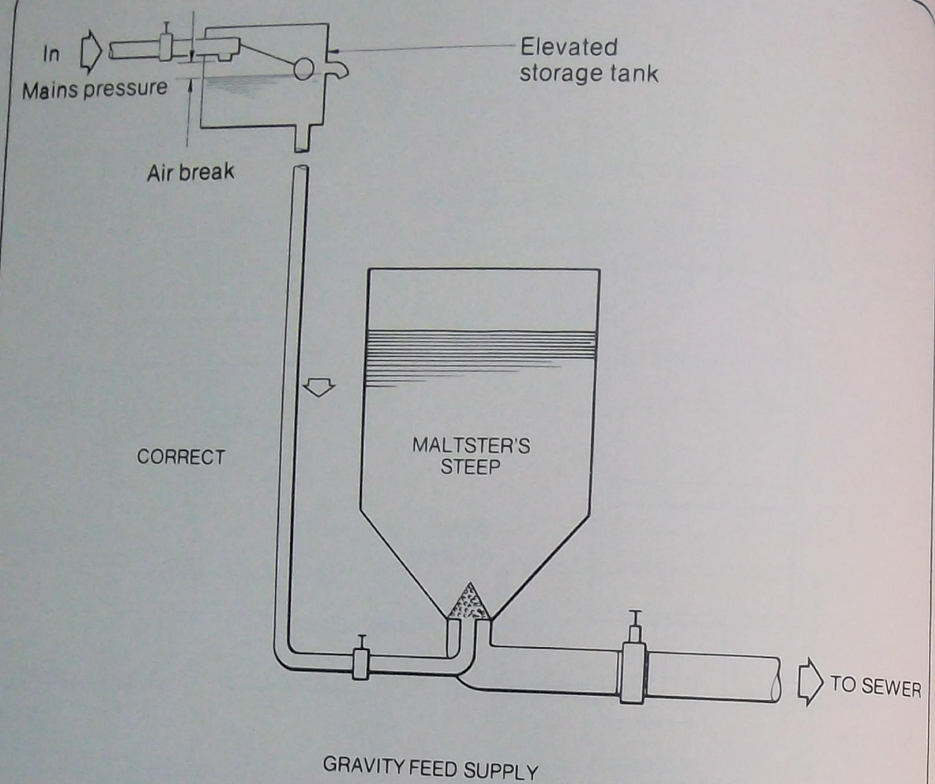
The diagrams show the correct and incorrect methods of connecting mains pressure supply to sausage making machines. The correct method has a physical air gap between the cylinder containing the sausage meat and the cylinder containing mains pressure water.

In the incorrect method, the water in the cylinder becomes polluted and in the event of a drop in pressure due to a burst service pipe or shutting off the main, the polluted water could find its way into the service system.

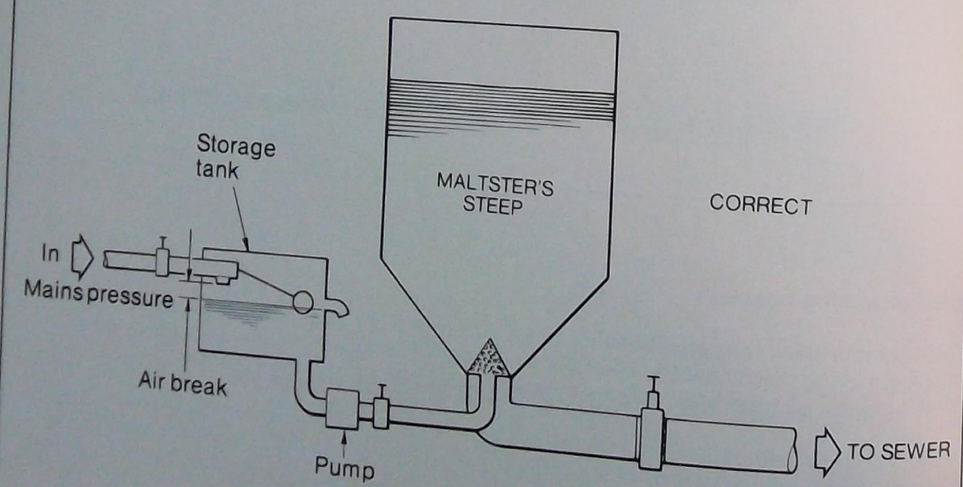
The incorrect method is not permitted.

Maltster's steep

The following illustrations show the various methods of correct connection and one that is incorrect.

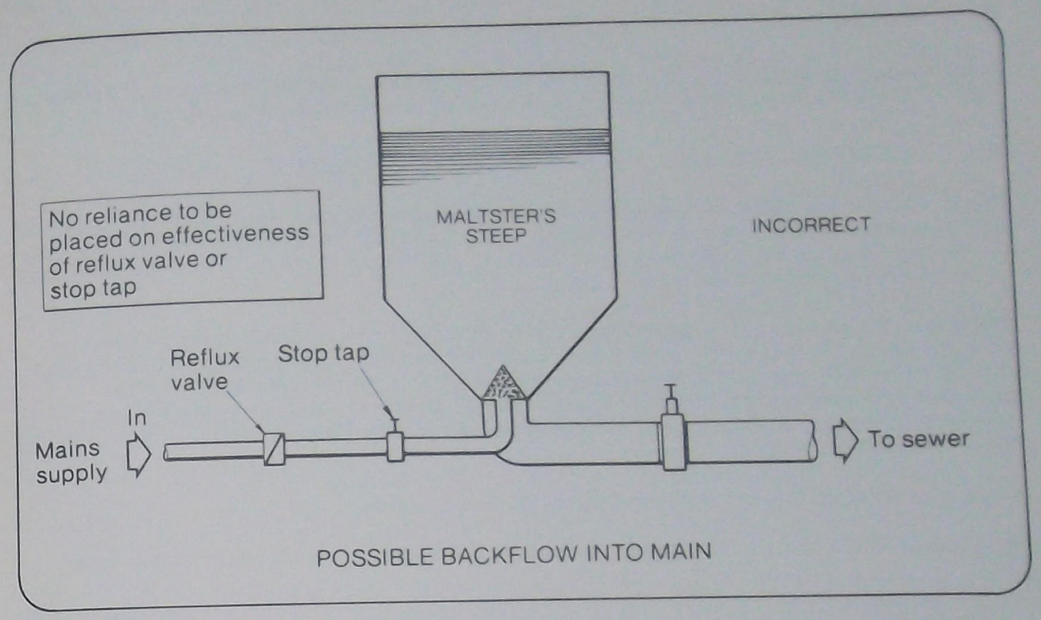


GRAVITY FEED SUPPLY



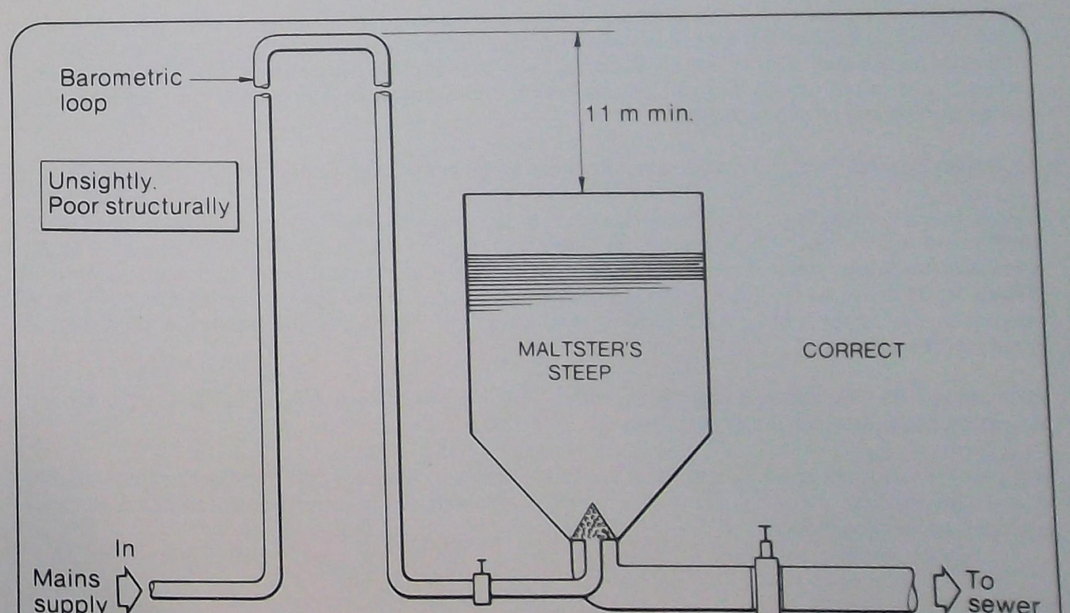
HIGH PRESSURE SUPPLY

PREVENTION OF BACKFLOW IN MALTSTER'S STEEPS



POSSIBLE BACKFLOW INTO MAIN

If a burst occurred in the main at the time water was being supplied to the steep, backflow could be set up in the service and the liquid contents of the steep drawn into the main because no reliance can be placed on the continued effective operation of the stop tap and the reflux valve.



PREVENTION OF BACKFLOW IN MALTSTER'S STEEPS

4 WATER

Even if a plumber is not involved in the collection, storage and distribution of water on a regional basis, it is well for him to know what it is he is handling and how it all comes about.

4.1 COMPOSITION AND CHARACTERISTICS OF WATER

Water is an indispensable item for sustaining human, animal and plant life on earth. Its scarcity or lack of presence endangers or is fatal to any of those three forms of life. It is no doubt, like many of nature's commodities, to be treated with respect, used economically and to the best advantage of life's sake. It certainly must not be wasted.

Water is a combination of two gases, hydrogen and oxygen in the proportion of two to one. Its chemical symbol is H_2O which in chemistry means that two atoms of hydrogen have combined with one atom of oxygen to form one molecule of water. The symbol represents only the composition of pure water such as is obtained through distillation, and in this state, it is a tasteless, odourless, transparent and colourless liquid, but when seen through considerable depth it can take on a bluish-green colouring.

Water may occur in three different physical conditions or states:

- In the solid state as ice. This condition starts at 0 °C and continues at lower temperatures.
- In the liquid state between the temperature range of 0 °C to 100 °C when it is generally referred to as water.
- In the gaseous state as steam at 100 °C and at higher temperatures.

NOTE:

Depending on certain conditions, both the ice and liquid state can exist at 0 °C.

Pure water, in the strict chemical sense, is unlikely to exist in nature. The purest water occurring in nature could be expected to be rain-water as it leaves the rain cloud over areas where there is no atmospheric pollution. This is unlikely to be the case over densely populated or, highly industrialised areas or over areas, where through volcanic activity, the atmosphere may be laden with volcanic dust, ashes or a variety of gas particles.

In falling to earth from the cloud, water collects a number of impurities from the atmosphere.

Water has the capacity to absorb gases and to dissolve many solids. In its downward travel to earth, as a result of collecting impurities, and depending on the type of ground on which it falls, the composition of water is altered. We have all heard the terms 'soft water' and 'hard water' used. These terms are used to indicate the capacity of water to dissolve soap and form suds. The 'softer' the water, the easier it is for suds to form from soap, and the 'harder' the water, the more difficult it becomes to do so.

Rain-water that has fallen on granite or other volcanic types of rock will usually be soft, clear and sparkling because such rocks have little effect on water.

If it falls on boggy or peat-type soil, the water may remain relatively soft, but may become slightly acidulated and take on a dirty brown appearance. Although not pleasant in appearance, such water may still be wholesome.

Water may fall on , or penetrate through deposits of lime or magnesia. As these dissolve in water, they make the water 'hard'. It tends to be a little more sparkling than in the other cases mentioned, and although its capacity to dissolve soap is much reduced, it may nevertheless be quite suitable for normal domestic use or for drinking.

4.2 PURIFICATION OF WATER

Purification of water can take place:

- Naturally
- Artificially

4.2.1 Natural purification

Water purification in nature takes place mostly in either of two ways or in both. They are:

- Purification by oxidisation
  - This takes place mostly in streams where organic matter that the water may contain is oxidised by coming in contact with the oxygen in the air.
- Purification by sedimentation
  - Occurs in slow streams and, to a larger extent, in lakes and in reservoirs. Exposed to sunlight, many bacteria are killed. Solid particles sink to the bottom and carry a large proportion of bacteria with them. Water provides unsuitable conditions for many pathogenic organisms which, being accustomed to life at blood temperature, gradually die out in water where they also have to compete with normal and harmless bacteria.

NOTE:

By seeping through various layers of soil and rock formation, water can also be purified by natural filtration and arrive at its collecting point reasonably wholesome.

4.2.2 Artificial purification

Special purification plants may have to be installed to purify the water needed for industrial processes. Town water supply originating from rivers or water run-off which has traversed polluted areas, has to be purified and sterilised before it is released into mains for consumption by being passed through purification plants and by the addition of certain chemicals.

4.3 WATER CATCHMENT AND STORAGE

4.3.1 Catchment areas

High standards of health and the provision of suitable conveniences for modern life demand an adequate supply of wholesome water. Where water occurs in unlimited quantities and is suitably located, such as at a higher level than the city or cities to be supplied, the problem of converting it to use is relatively simpler than in the case where the city is at a higher level than the water level, or where one city is located downstream of another on the same river. Where rivers are the only source of possible water supply, the prevention of stream pollution becomes very important.

Rain water which falls on the earth is partially:

- lost by evaporation from the ground or through the agency of vegetation;
- run off over the ground surface as surface or stormwater;
- soaked into the soil until it reaches groundwater.

Most rivers are fed partly with water from surface catchment run-off, partly from springs and seepage from groundwater and in some cases from melting snow and glaciers in mountainous areas.

Surface water flows into depressions, to water courses, rivers and lakes. During this course, it dissolves or carries in suspension a number of impurities. It may traverse polluted ground, such as town streets, farm yards, manured or grazing land, and collects on the way, domestic or industrial drainage. It is obvious that the longer such water has to travel over settled land, the more likely it is for it to be unfit for human consumption and it is equally obvious that the further away the catchment area is located from civilised settlements, the greater the probability becomes that a suitable supply of safe water, free from harmful organisms, is available.

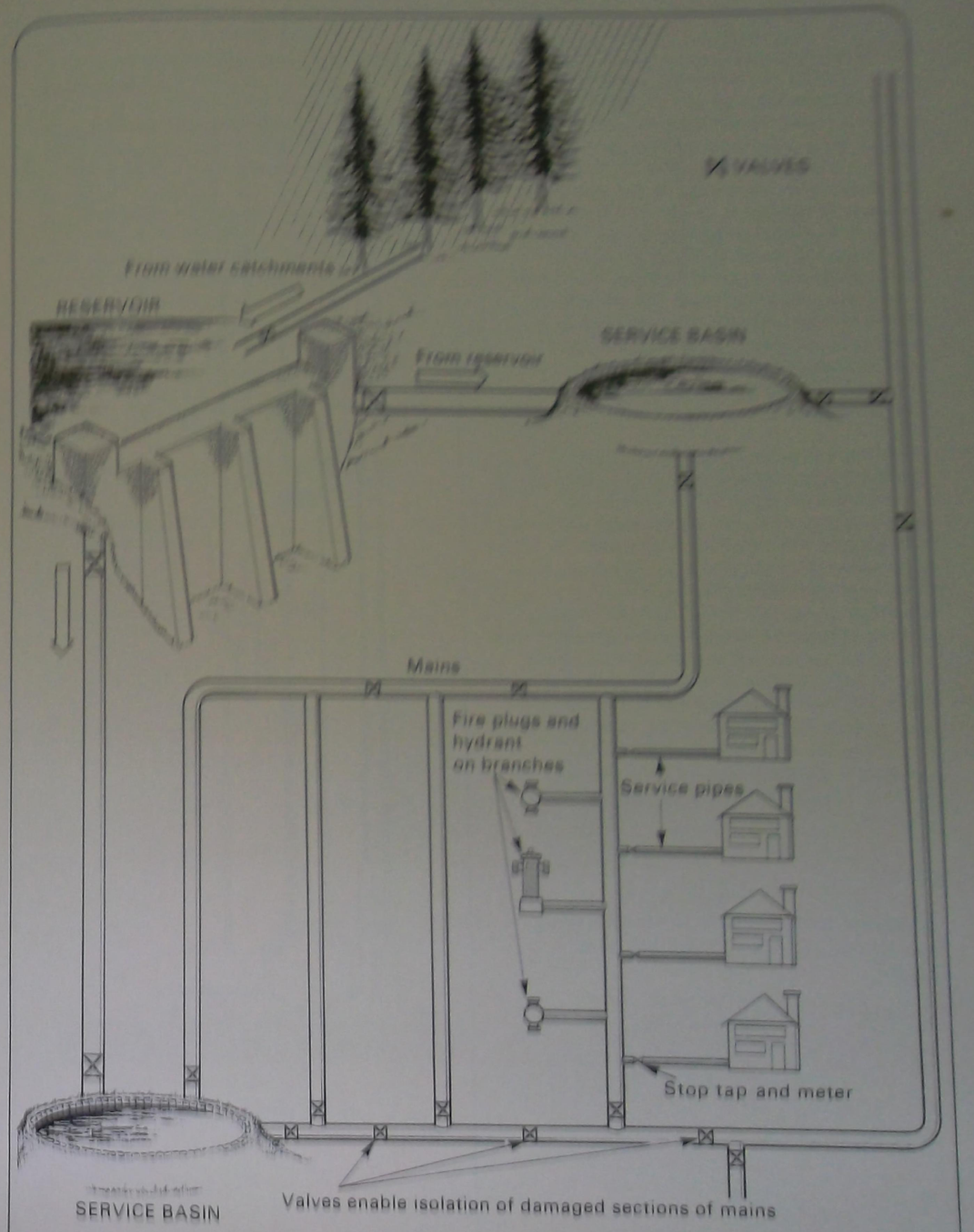
Unfortunately, such ideal conditions as the last mentioned are unlikely to occur. Catchment areas are usually accessible to humans and animals. Water has the capacity to gather, sustain and propagate disease germs (typhoid, cholera and other bowel bacteria). It is therefore best to prevent access to catchment areas by humans and animals alike, especially dogs which could be carriers of the hydatids germ.

Where it is not possible to deny access to catchment areas, the proper sanitary arrangements must be provided. Water from catchment areas located within populated areas must be filtered and sterilised before release into water-mains for human consumption.

4.3.2 Water storage

The storage of town water supply is usually done by constructing a dam or weir at a suitable location in a river valley across the course of the stream and at an elevation well above that of the area to be supplied. The water so dammed-off builds up behind the weir and forms a reservoir which should hold sufficient water for the daily requirements under normal circumstances, as well as providing sufficient reserves to cope for dry periods when the stream supplying the reservoir may reduce its flow or dry up completely.

Where no suitable valley is available, a reservoir may be built by digging away earth and by constructing strengthened and elevated sides around the depression dug out.



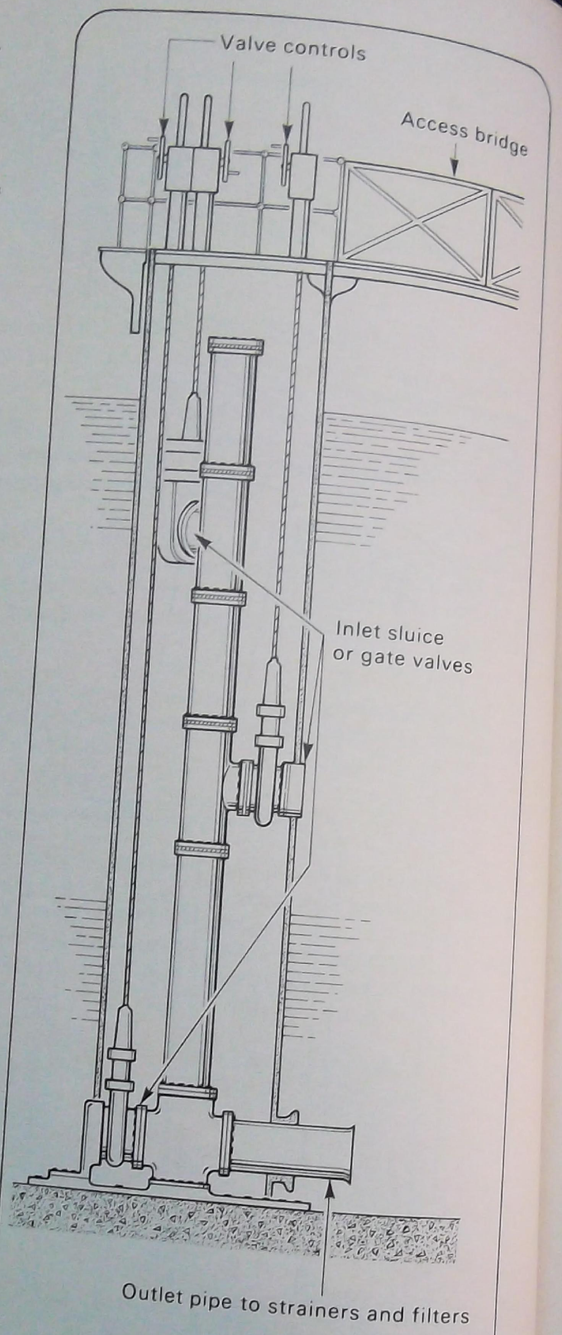
THE RETICULATION SYSTEM

Purification of water in reservoirs occurs mostly by sedimentation, as we have seen. The purest water occurs usually between 30-60 centimetres below the water surface, and to take advantage of this, valve towers are built in the reservoirs with inlet valves at various levels. The reservoir level can be read on a gauge or is marked on the side of the tower, and depending on the level read, the appropriate valve, controlled from the top of the tower can be opened for supplying the water from the appropriate level below the reservoir surface. The other inlet valves remain closed. The illustration shows a diagrammatic cross-section of a tower with 3 valves. Depending on the reservoir depth, more valves can be installed or more towers with valves at various levels.

From the valve tower outlet, the water is passed through strainers or filters, then by gravity through pipes to the area to be served. Sometimes the water is conveyed to that area by means of open channels. In either case, it is usually led into one or more service basins situated near the township or suburb. These service basins, like the reservoirs, are located above the area to be served and are designed to hold several days' supply of water so that in the event of a burst main upstream of them, the town supply is not interrupted. In addition, they allow the main supply pipe to be reduced in diameter for the local supply and they also serve as line pressure reducers.

NOTE:

To improve dental health, some authorities have introduced fluoride into the water supply.



VALVE TOWER

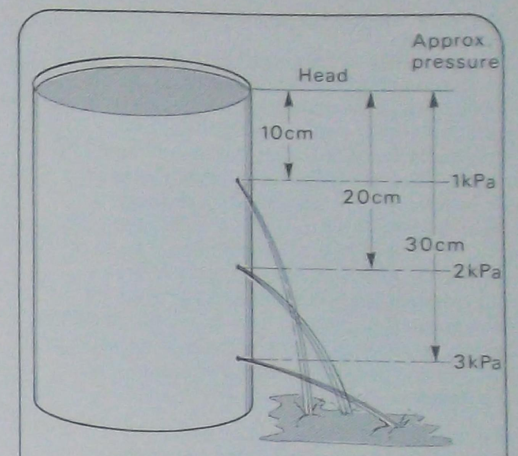
4.4 WATER PRESSURE

The branch of science that deals with fluids at rest is called:
'Hydrostatics' and that which deals with fluids in motion: 'Hydraulics'. It is necessary for plumbers to know something about these two in the exercise of their trade.

For instance, a storage tank filled with water is subject to hydrostatic pressure. A water supply reticulation system is subject to the laws of hydraulics.

CONVERSIONS:

10 mm = 1 cm = 0.1 kPa
10 cm = 100 mm = 1 kPa
100 cm = 1000 mm = 1 m = 10 kPa
1000 cm = 10 m = 100 kPa



Pressure proportional to depth,
the greater the depth, the greater the pressure

STATIC HEAD

NOTES

4.4.1 Hydrostatics

The intensity of pressure exerted by water is directly proportional to the depth of the water and is measured in kilopascals (kPa). When water is static, the depth at any particular point is called the static head. Static head is measured in centimetres or in metres. The abbreviations used for centimetres or metres of water head are cm H_2O or m H_2O. For any given static head of water, the pressure on each unit of area — for example square centimetre (cm^2) — of any surface in contact with the water is the same, regardless of the volume of water held in the container, or the shape of the container.

If a number of containers of water is connected together by tubes below the surface of the water and the upper ends are not sealed, the water will stand at the same level in each, regardless of their size or shape. (See: 'Bricklaying Fundamentals'). Since pressure at the same head is uniform, the pressure at the bottom of all the containers is the same although they may not hold the same amount of water.

NOTE:

Every 10 cm of static waterhead corresponds to approximately 1 kPa (actual pressure = 0.981 kPa).

For any given head, water transmits pressure equally in all directions.

This is illustrated by a fireman's hose which first lies flat and becomes cylindrical when under water pressure.

If a closed cylinder is supplied with water from a tank, the pressure on the top, sides and bottom of the cylinder will differ only in proportion to the difference in head at each particular location.

The pressure at the top of the cylinder is caused by head A.

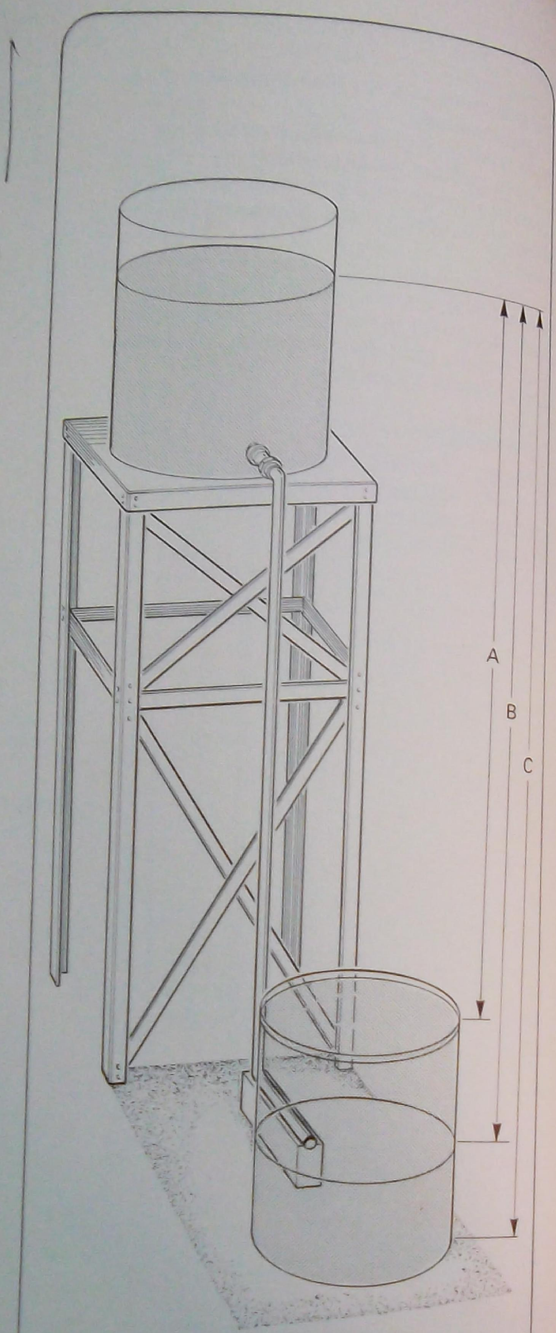
The pressure at the bottom of the cylinder is caused by head C.

The average pressure anywhere on the sides of the cylinder can be calculated from head B.

$$\text{Pressure B} = \frac{\text{Pressure at C} - \text{Pressure A}}{2}$$

$$\text{or} = \frac{\text{Head C} - \text{Head A}}{2}$$

'Head' is of course the same as saying 'pressure' in a different way.



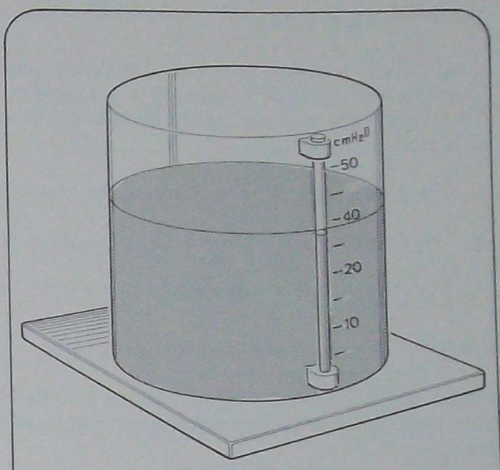
PRESSURE WITHIN A TANK

If a large diameter pipe and a small diameter pipe are fed with water at the same head, the pressure (kPa) in each will be the same, but the larger pipe will deliver more water because of its greater capacity.

4.4.2 Measuring water pressure

Water pressure may be measured in several ways. The simplest form of measuring device is a manometer. A manometer consists of a vertical glass tube fitted on the outside of a water container. A scale, graduated in centimetres is fixed beside the tube. Because the water will stand at the same head in both the container and the manometer, the head of water in the container may be read off the scale in cm H_2O. From this, the pressure may be readily calculated.

A head of water of 1 centimetre has a pressure value of 0.0980638 kPa. Mathematically, this is an awkward basis to use for comparisons. It is much more useful to regard 10 cm H_2O as having a value of approximately 0.98 kPa, or if the head is in metres, we can use the formula: 'metres head × 9.8 = pressure in kPa'.



MANOMETER

Thus, if the cm H_2O scale of the manometer indicates a head of, for example, 40 cm (400 mm), then the pressure at the bottom of the container may be calculated as follows:

40 cm = 4 times 10 cm; therefore, the pressure exerted will be 4 times that exerted by 10 cm; or

4 × 0.98 = 3.92 kPa. Using m, we get: 0.4 × 9.8 = 3.92 kPa also.

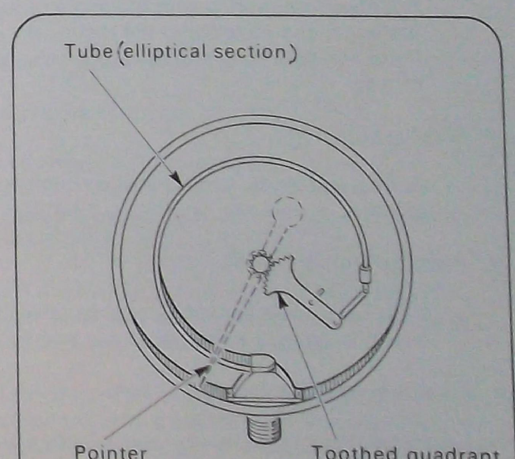
For most practical purposes, the simple formulae: 10 cm H_2O = 1 kPa, or 1 m H_2O = 10 kPa may be used to calculate:

- Pressure, when the head of water is known.
- Head of water when the pressure is known.

4.4.3 Bourdon pressure gauge

This instrument is commonly used to measure pressure in town water systems. The gauge contains a flat, curved tube closed at one end. The open end of the tube is attached to the outer case of the gauge and fitted with a coupling for attachment to the water supply system.

The closed end of the tube is connected by gears to a pointer. When the gauge is coupled to the water supply and pressure is applied, the flat tube tends to straighten, causing the pointer to indicate the pressure on a circular scale, calibrated in kPa on the face of the gauge. The principle of operation of the Bourdon gauge may be demonstrated by connecting a garden hose to a tap, laying the hose in a curve and turning on the water. The hose will tend to straighten itself under the influence of the water pressure.



BOURDON PRESSURE GAUGE

4.4.4 Hydraulics

A high static pressure does not necessarily mean that a large volume of water will be discharged from the end of a pipe connected to a source of supply. Friction between the moving water and the inside surface of the pipe is a major factor in the restriction of the volume of water delivered by a pipe. In general:

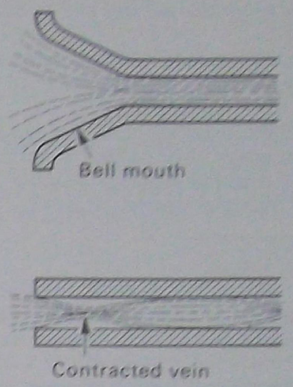
- The greater the velocity of water, the greater the friction.
- The smaller the diameter of the pipe, the greater the friction.
- The rougher the inside surface of the pipe, the greater the friction.

4.4.5 Flow of water through pipes

Whilst static pressure is a guide to the volume of water that might be expected to flow through a pipe system, other factors govern the volume which will actually flow. The most important factors are:

- The diameter of the pipe.
  - — The larger the bore of the pipe, the more water it can deliver.
- The length of the pipe.
  - — The longer the pipe, the greater the friction between the water and the inside surface of the pipe.
- The condition of the pipes.
  - — Soft water is rich in oxygen which quickly rusts iron. The rust accumulates inside the pipe and reduces the effective inside diameter of the pipe by the growth of rust carbuncles. They cause more friction and eddies through the rough surface and restrict the water flow.
- Changes in direction.
  - — Sharp bends cause eddies which, in turn, cause friction and restriction of the water flow. Frictional loss varies with the angle of the bend and the radius of curvature. The sharper the angle and the shorter the radius, the greater frictional losses will be. A radius of 5 times the pipe bore on the centre line gives no more friction than the same straight length of pipe.
- Quality of jointing.
  - — Burred pipe ends, excess sealing compound and gaps between pipe ends restrict the flow of water.
- Passage through valves.
  - — Each time water passes through a valve, it is restricted and usually forced to change direction once or twice, depending on the design of the valve.
- Enlargement or contraction of size.
  - — To gain maximum flow, enlargements and contractions of pipe diameter should be made as gradual as possible.

- Shape of outlet
  - — The stream lines of a jet of water converge to form a contracted core when released from the restraint imposed by passage through a pipe or an outlet. The effect is called 'vena contracta'. The shape of the outlet influences this action and has an effect on the volume of water which can be delivered. Through the action of the vena contracta, the volume of discharge is restricted to the cross-sectional area of the contracted vein instead of that of the full pipe cross-section.



VENA CONTRACTA

When pipelines are short, the effect of vena contracta on the volume of water delivered is an important consideration. The effect can be partially overcome by making the outlet bell-shaped. However, when pipe lines are long, pipe friction is a much more important factor and for all practical purposes, vena contracta can be ignored.

4.5 DISTRIBUTION OF WATER

4.5.1 The reticulation system

The network of pipes (called mains) used to distribute water throughout towns and cities is called the reticulation system. The mains are laid in streets and interconnected with each other around blocks of buildings and controlled by sluice valves so that:

- a constant movement of water is maintained to avoid water stagnation in pipes;
- alternative routes for water supply are available in case of a main bursting;
- water supply for fire fighting flows to the fire hydrants(s) by several routes.

The pipes which carry water from the mains to houses are called: SERVICE PIPES; those which carry water to hydrants and fire plugs are called: BRANCHES.

Hydrants are usually fixed on kerbs or footpaths and their water supply comes from a branch connected to a main. Fire plugs located below ground level, and protected by special cast iron covers, are generally connected to a branch taken vertically upwards from a main.

The position of a fire plug or a valve is usually indicated by a white peg or a mark on the kerb, footpath or building in direct line with the plug. Sometimes, the distance from that mark to the plug or valve is indicated also. The markings are usually in a code peculiar to each Water Supply Authority and a knowledge of this code will assist the plumber in locating the mains.

When it is necessary to locate and gain access to a main, the approximate location of it can be found by taking a line between 2 adjacent fire plug covers.

4.5.2 Materials for mains

Materials used for water-mains may be metal (mild steel, cast steel, copper, cast iron), reinforced concrete, asbestos cement and plastic (UPVC or Polyethylene).

The manufacturers for these provide also a great range of fittings suitable for installation of complete water supply mains carried out with their products.

The materials used for pipes depend on the type of ground in which mains are to be laid, the volume of water to be carried and the materials used for the existing mains to which the new main is to be connected. Costs of materials and of laying also play a big role in determining which is the most suitable material to use.

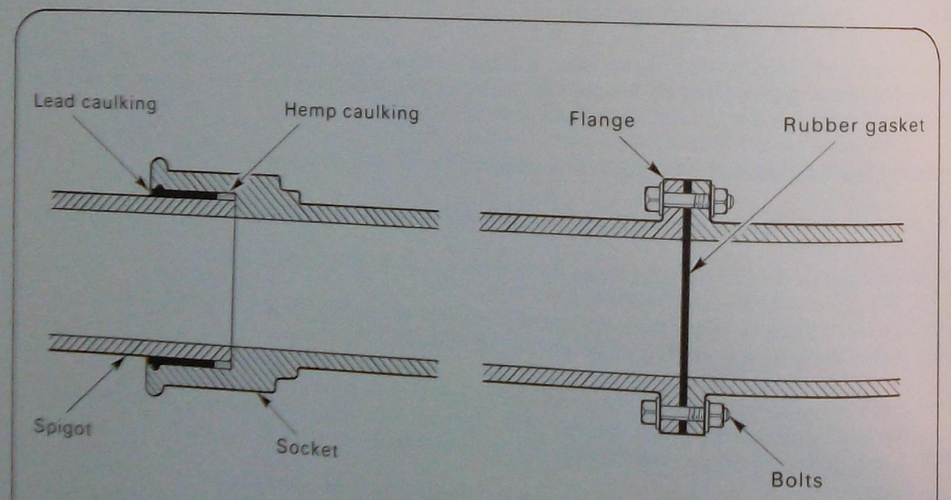
NOTE:

The various types of joints used and the fittings available as well as the methods of assembly for the different types of materials are outside the scope for discussion in this manual.

The trainee who wishes to increase his knowledge of the details for the installation of mains or other pipe installations (sewerage, drainage, irrigation, industrial waste disposal, etc.) should obtain the relevant technical brochures that manufacturers make available about their products.

4.5.3 Cast iron pipes — Types and assembly

In former times, pipes made of cast iron were cast in sand moulds and the most common joints encountered (and which will still be met in older installations) were either the lead-caulked joint to secure the spigot end of one pipe to the socket end of another downstream or the flanged joint. In the last case, the flanges were cast integrally with the pipe barrels and the joints made by bolting the flanges together with a rubber gasket in between to make the joint watertight.



CAST IRON JOINTS (OLD TYPE)

Modern manufacture of cast iron pipes now uses the centrifugal casting method which results in a more homogeneous metal structure of greater strength.

The modern type of cast iron pipe joints are:

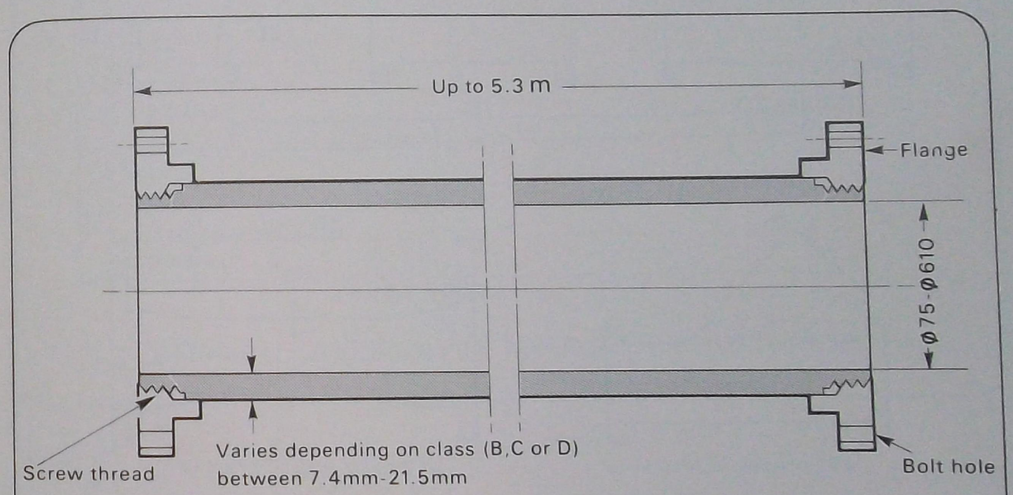
- The flanged type.
- The rubber-sealed, push-on type.

The flanged type

The ends of the straight pipe barrel are provided with a machine-turned screw thread and the flange, also machined, is screwed on tight to the barrel by machine to a predetermined torque. Before this is done, the threads are coated with a special epoxy resin which provides the necessary sealing. The part of the barrel that protrudes past the outer flange face is machined off, level with the flange face.

These pipes can usually be supplied flanged at both ends as illustrated or with one end flanged and the other socketed, or with one end flanged and the other spigoted.

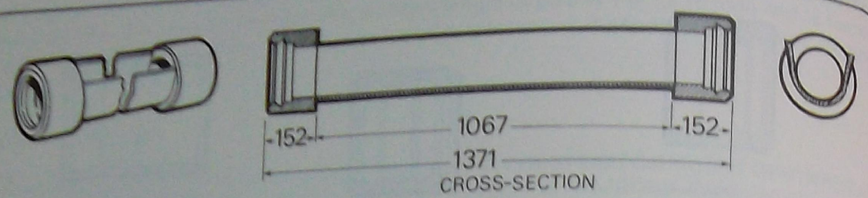
Wall thickness varies according to the class of pipe specified; class B being the thinnest, class D the thickest and class C in between. This last one is the most used for standard requirements.



STRAIGHT CAST IRON PIPE (FLANGED)

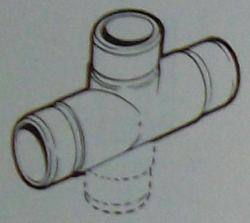
In some cases, specifications may call for the pipes to be lined with cement mortar. The thickness of this lining depends on the diameter of the pipe and the task it has to perform. As for the manufacture of pipes, this aspect is subject to quality control and the requirements are laid down in the appropriate Australian Standard.

Suitable fittings to match a flanged mains system are available and some of them are illustrated (see page 32). They can also be made and supplied with cement mortar linings to match the pipe lining.

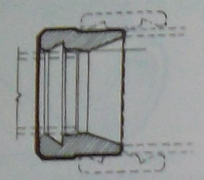


MANHOLE HALF PIPE

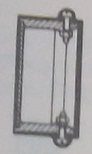
To form channel in manhole floors and provide flexible joint in manhole walls for adjoining pipes



TEE AND CROSS

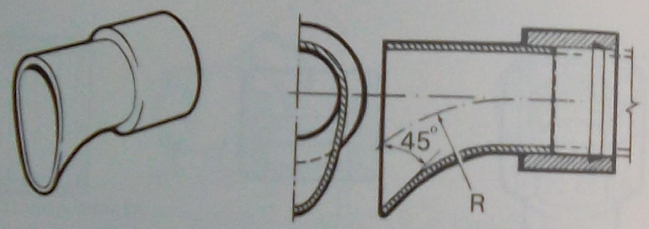


REDUCER



ROLL-ON INSPECTION CAP
(PRODUCED IN W A)

Used on branch of square or slop junctions or on end of pipe. Removable for inspection purposes



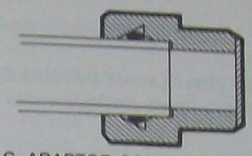
SPILLWAY PIPE

To provide a smooth transition from the manhole wall to the manhole ben

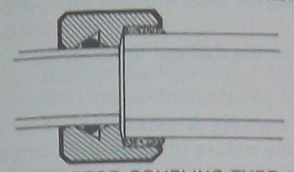
SPECIAL F.R. FITTINGS

NOTE:

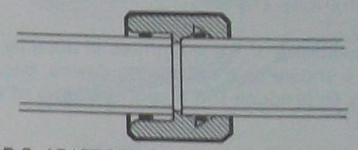
All other fittings, other than junctions, bends and IO's made from other materials, may be used in conjuction with F.R. pipe with the aid of suitable adaptors, depending on the appropriate Authority.



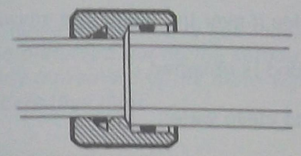
F.R.C. ADAPTOR COUPLING — TYPE 3 (DISCED)
F.R.C. SPIGOT TO RRVC SOCKET



F.R.C. ADAPTOR COUPLING TYPE 1
F.R.C. SPIGOT TO MORTAR JOINT
VC SPIGOT

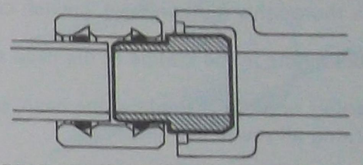


F.R.C. ADAPTOR COUPLING — TYPE 4
F.R.C. SPIGOT TO CI SOIL PIPE SPIGOT

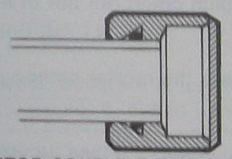


F.R.C. ADAPTOR COUPLING TYPE 2
F.R.C. SPIGOT TO RRVC SPIGOT

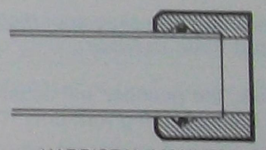
225 mm also suitable for polyester rubber ring V C spigot



F.R.C. ADAPTOR COUPLING TYPE 5
F.R.C. COUPLING TO RRVC SOCKET



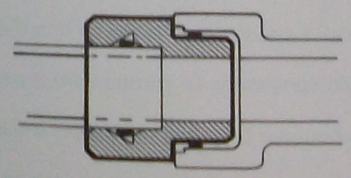
F.R.C. ADAPTOR COUPLING TYPE 2 (DISCED)
F.R.C. SPIGOT TO RRVC SPIGOT



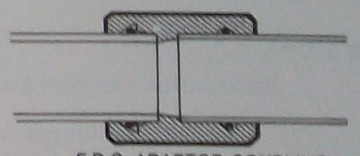
HARDISEAL MANHOLE F.R.C. COUPLING

To provide a flexible joint for UPVC pipe adjoining manhole.

Cast in manhole wall.



F.R.C. ADAPTOR COUPLING — TYPE 3
F.R.C. SPIGOT TO RRVC SPIGOT



F.R.C. ADAPTOR COUPLING
F.R.C. SPIGOT TO UPVC SPIGOT

F.R.C. ADAPTOR COUPLINGS

5.2 CEMENT COMPO

This is another name sometimes used for cement mortar.

It is used to make the joints in vitrified clay pipes (where permitted), to seal-in the discs or the plugs in inspection openings or to seal-off any holes made in walls or in drives for the passing through of pipe work.

Proper cement mortar is made by mixing carefully measured quantities of cement and sand with water.

Suitable measuring and mixing techniques are explained in detail in the manual 'Bricklaying Fundamentals' (13-1).

The measuring of the quantities is done by volume, using marked buckets or similar. It is best not to use a shovel as a measuring device, because the difference in the nature of sand and cement is unlikely to produce the prescribed ratio of the mix. To prepare a cement mortar mix, proceed as follows:

- Measure out the required parts of sand and dump them on a mixing board or such like level surface.
- Measure out the required amount of cement and sprinkle it over the measured amount of sand.
- Mix thoroughly until an even, greyish coloured compound is obtained.
- Make a hole in the middle of the heap and carefully add clean water.
- Starting from the outside of the heap, gradually shovel the cement/sand mixture into the water, working all round the heap.
- Keep mixing the compound (and if necessary, add water a little at a time) until a mixture is obtained that will hold together when rolled into a ball. Minimum mixing time: 3 minutes.
  - — Adding too much water will result in a sloppy mixture which could run out of a joint and cause an obstruction.
  - — Too much water makes poor mortar and tends to segregate the mortar components rather than bind them together.

In drainage work, the plumber will usually have to work with two types of mixes, unless otherwise prescribed by the Approving Authority. They are:

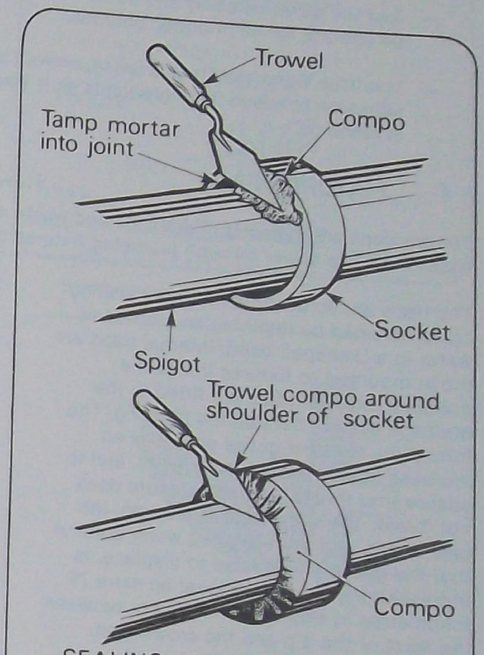
- A 1:2 mix (1 part cement, 2 parts of sand) for the sealing-in of stoneware discs into inspection openings or for mortar jointing of pipes.
- A 1:4 mix for rendering work.

To make a mortar seal, proceed as follows:

- Check that the spigot is properly seated and aligned into its socket.
  - — If necessary, support the spigot end.
- Using a trowel, tamp in the cement mortar between spigot and socket, making sure it is done all around the joint and that the joint is completely filled.
  - — Start at the bottom of the socket, working up towards the top from both sides in turn.
- Finish the joint off smooth by trowelling the mortar around the shoulder of the socket.

NOTE:

The mortar takes some time to set. Pipes must not be disturbed during the setting period as any movement of the pipes will result in a defective joint.



SEALING A PIPE JOINT WITH CEMENT COMPO

5.3 CONCRETE

In drainage work, concrete is used as a support bed for disconnector gully, some fittings and for pipes in some cases. It is also used for the construction of anchor blocks and mounds.

The two mixes mostly used in drainage work are:

- A 1:2:3 mix (1 cement, 2 sand, 3 aggregate parts by volume) for use as bedding for fittings.
- A 1:2:4 mix for anchor blocks.

The size of the aggregate (screenings) is nominally specified as 14 mm.

To mix a batch of specified concrete proceed as follows:

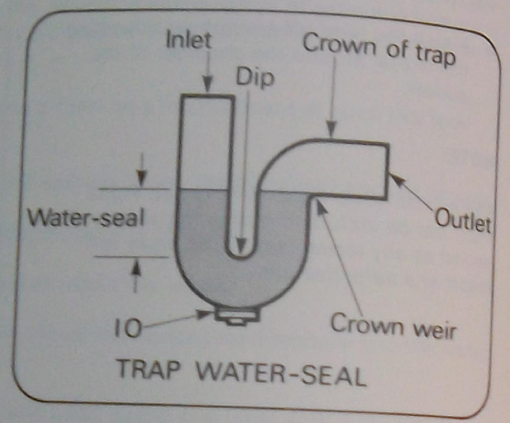
- Measure the quantity of screenings required and place them on a mixing board.
- Measure the amount of sand required and place it on top of the screenings.
- Add the measured amount of cement to the heap and mix all three ingredients until all are evenly distributed throughout the mix.

- Add clean water slowly and continue mixing until an easily workable (plastic) mixture is obtained.
  - Add the water carefully and do not use too much or too little. Either way, the concrete will be useless for its intended purpose.
  - Too little water results in a loose, uneven and crumbly structure; too much prevents proper adhesion between the ingredients as it washes the cement away from the sand and the screenings.

5.4 FIXTURE TRAPS

Fixture traps are installed in drainage and waste systems to prevent the discharge of noxious gases from the sewer through plumbing fixtures into the house.

The traps are so designed that the sealing-off is obtained by retaining an amount of water in a U-shaped bend. Internal traps are those mounted to fixtures inside the building; external traps are fitted to the drainage system outside the building. The formation of sewer gases produces an increase in pressure in the system, and to ensure that this increased pressure does not 'break' the water-seal in the trap, the seal depth, and therefore the water column that the gases would have to displace, is increased by allowing at least an extra 75 millimetres in water column height between the level of the dip and the crown weir.



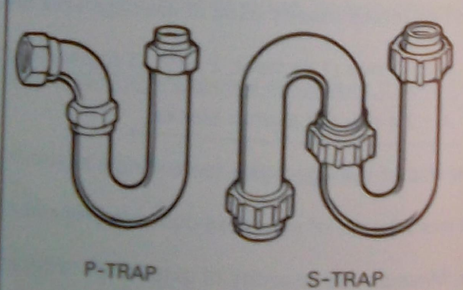
TRAP WATER-SEAL

Some fixture traps have an inspection opening, closed off by a screwed plug and washer at their base for easy cleaning in case of a blockage.

There are two basic trap designs:

- the P-trap
- the S-trap

Installation of the P-trap is preferred, because it has less tendency to lose its water-seal through syphon action.



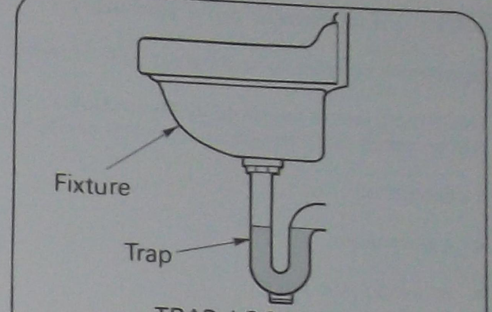
TRAPS FOR FIXTURES

To be effective, traps are fitted as close as possible to the fixture discharge opening to prevent loss of water-seal and to eliminate smell between the top of the water-seal and the fixture outlet.

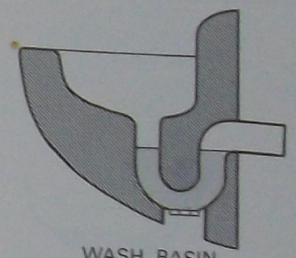
In some fixtures, the trap is incorporated in the structure of the fixture itself and usually manufactured from the same material as the fixture.

Most fixture traps are made from brass, copper or polypropylene, but in very old installations, some lead traps can still be encountered.

NOTES



TRAP LOCATION


WASH BASIN


TOILET

SOME FIXTURES WITH INTEGRAL TRAPS

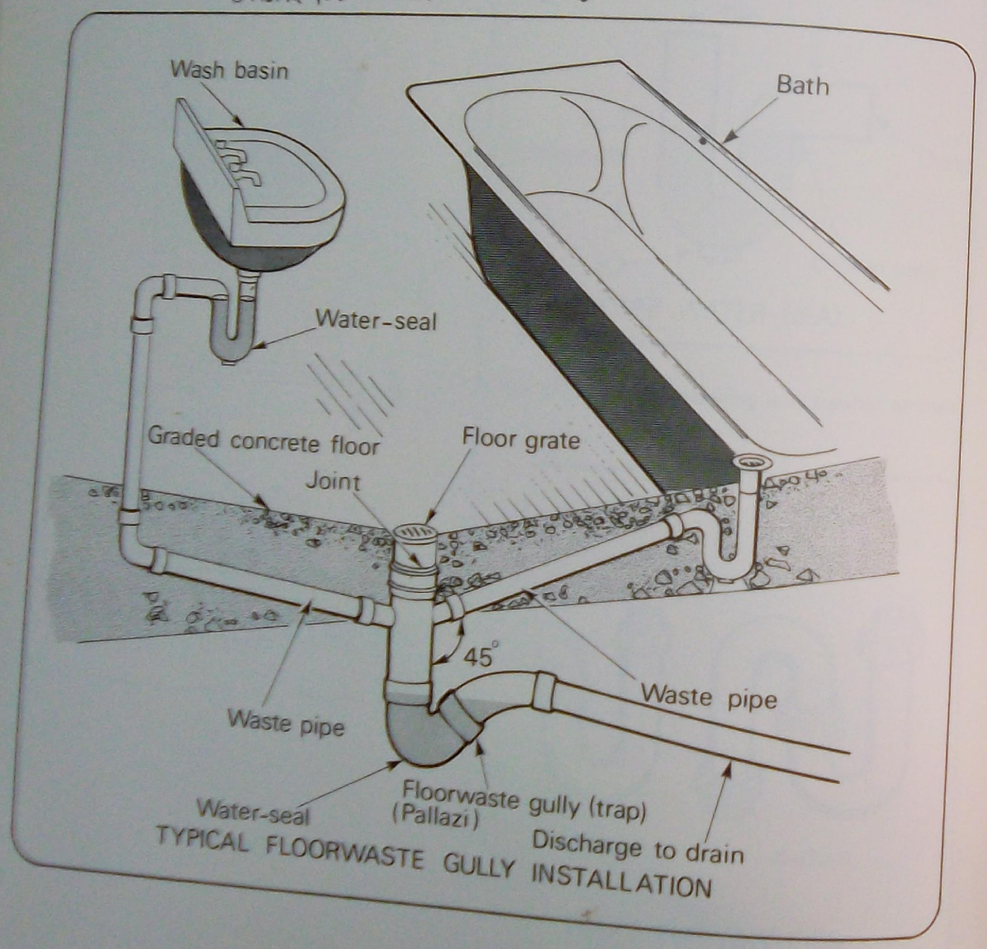
5.4.1 Floorwaste gully assembly

Sometimes referred to as a Pallazi gully or trap in some States of Australia.

This fitting, where approved by the local Authority, may be installed indoors. It has the advantage that it makes the connection of several sanitary fixtures to a common waste pipe easier.

It consists of:

- a floor grate
- an associated riser
- an inlet connector fitting with two or more connections
- a P-trap.



TYPICAL FLOORWASTE GULLY INSTALLATION

The floor grate is mounted flush with the sloping, impervious floor surface, either of the bathroom floor or the floor of the shower recess itself. When installed in the shower recess, it actually functions as the shower waste. However, if installed in the bathroom floor, it acts as a floorwaste plus taking the discharge from bath, basin and shower.

The risers are available in various lengths to suit the conditions of a variety of installations. The inlet sections or connectors can be obtained with a varying number of connections. The whole floorwaste gully assembly may be of brass or of UPVC. To join the various components of the brass floorwaste gully assembly, it is necessary to silver braze the joints. For the UPVC-built one, the joints are solvent welded. When a floorwaste gully assembly is installed, the National Code makes allowance for the individual fixture traps on the sanitary fixtures to be omitted, their tasks taken over by the floor trap (FWG).

NOTE:

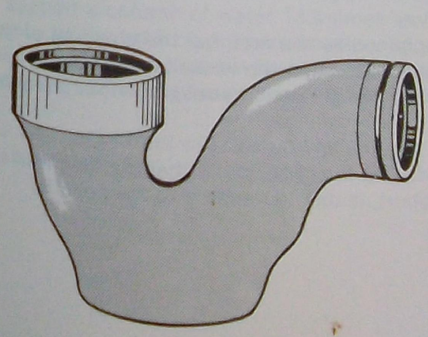
The local authorities should be consulted in relation to omitting the fixture traps.

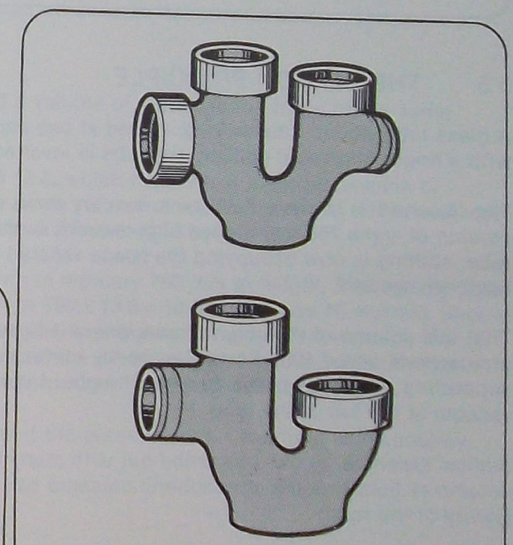
5.4.2 Drainage traps

Traps fitted in external drainage systems are usually laid underground. They are formed from VC, UPVC, or cast iron and have spigot and socket ends to fit the pipes and fittings of the drainage system. A flat base may be included for easy setting of the trap in a concrete bedding which should be at least 100 mm thick.

There are two basic types used today.

- The drainage trap, used in a disconnector gully installation is a fitting incorporating a water-seal that is used in the drainage system to separate the house drain from the waste discharge pipes. In conjunction with other fittings, it provides ventilation to such waste pipes.

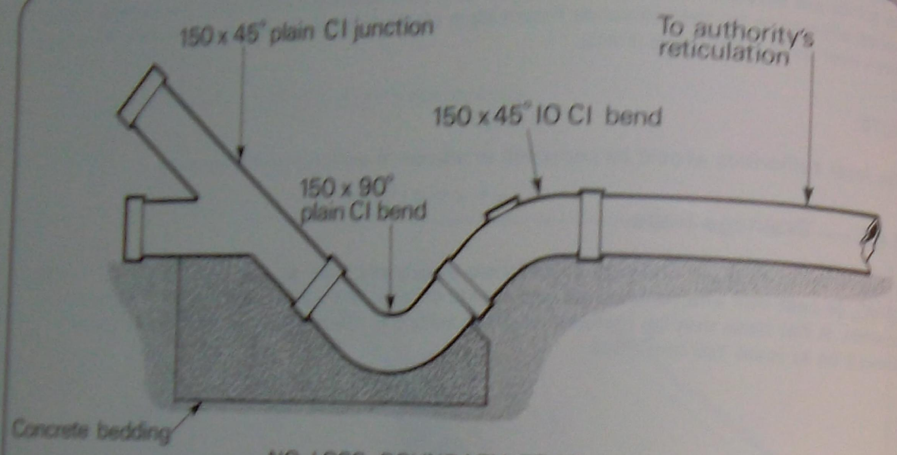

DRAINAGE TRAP (USED IN A DISCONNECTOR ASSEMBLY)


BOUNDARY TRAPS

- The boundary trap, is a drainage trap used to prevent the passage of sewer gases to the property drain.

- The 'no-loss' prefabricated boundary trap

This prefabricated boundary trap assembly is used in the State of Victoria for special purposes, namely to prevent loss of water-seal in the trap of large property connections, e.g. 150 mm. At the moment, it can only be used with the approval or the Governing Authority and only on the owner's responsibility. Refer to Section 7.2.2 in this book for complete installation.



NO-LOSS BOUNDARY TRAP

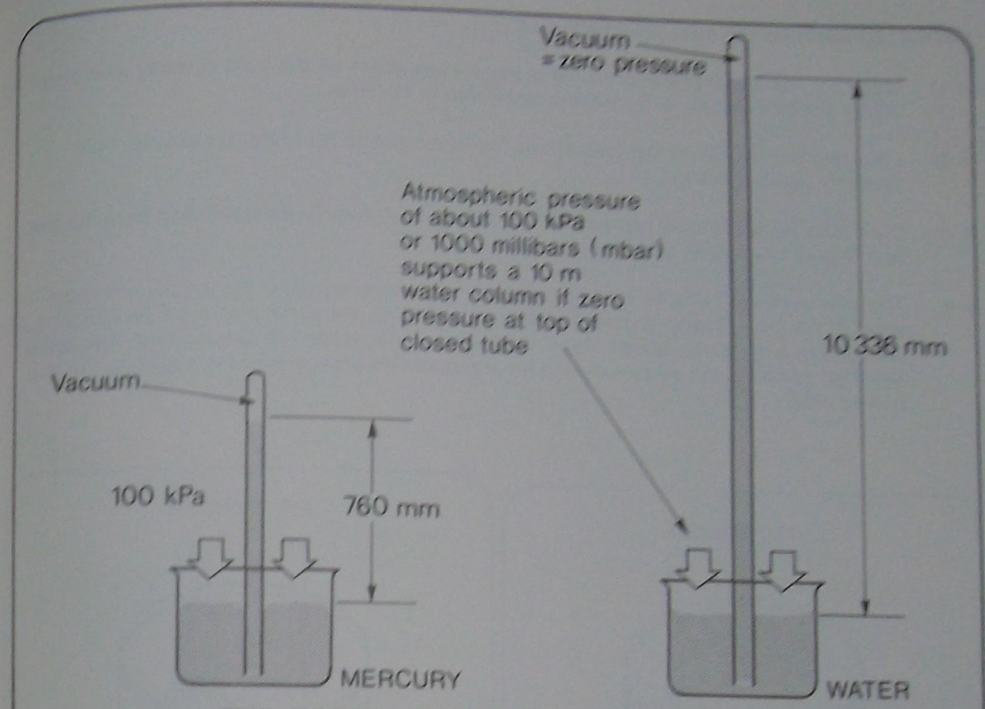
5.5 THE SYPHON PRINCIPLE

A glass tube, about 1 metre long, closed at one end is filled with mercury. Closing the open end with a finger to prevent spilling, the tube is inverted carefully into a container filled with mercury.

The observation is made that some mercury flows out of the tube into the vessel and that a column of some 760 millimetres high remains in the tube. As no air has been introduced in the tube, nothing is now occupying the space vacated by the mercury at the top of the tube; a vacuum has been created.

That this column of mercury remains where it is, is explained by the fact that the pressure of the atmosphere, about 100 kPA, acting on the surface of the mercury in the vessel, is capable of supporting that mass of mercury to a height of about 760 mm (76 centimetres), provided there is a vacuum at the top of the tube.

Similar experiments can be carried out with many fluids and it will be found that the height of the column of fluid that the atmospheric pressure can support, is directly related to the specific gravity of the fluid.



THE EFFECT OF ATMOSPHERIC PRESSURE

Specific gravity means: the ratio of the mass of a volume of matter to the mass of the same volume of pure water.

We know that the specific gravity of mercury is 13.6, which means that a certain volume of mercury has a mass 13.6 times greater than the same volume of water. Therefore, if 1 litre of water has a mass of 1 kg, then 1 litre of mercury will have a mass of 13.6 kg.

So, if the atmosphere is able to support a column of mercury 760 mm in height, it is equally able to support a column of water 13.6 times as high or $760 \times 13.6 = 10\,336$ mm (say 10 metres). Should the top of the tube be pierced, so allowing atmospheric pressure to replace the vacuum, the columns of fluid could not be supported any longer; the pressure inside and outside the tube becoming equal, the liquid levels would become the same inside and outside the tube.

The column of fluid will rise up again in the tube if the pressure above the fluid is lowered by suction.

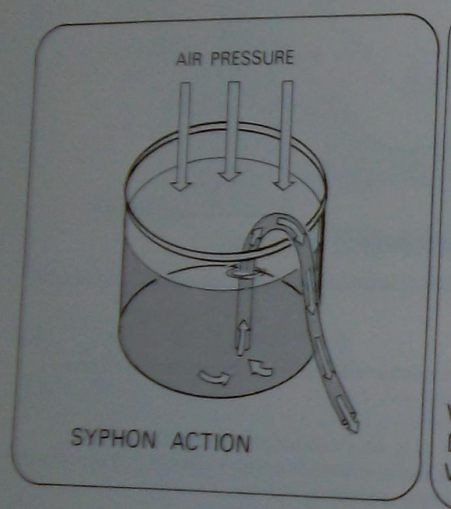
The syphon works on the principles discussed.

In 1: (page 57) The atmospheric pressure is equal everywhere on the fluid surface, including that inside the curved tube with one end immersed in the fluid.

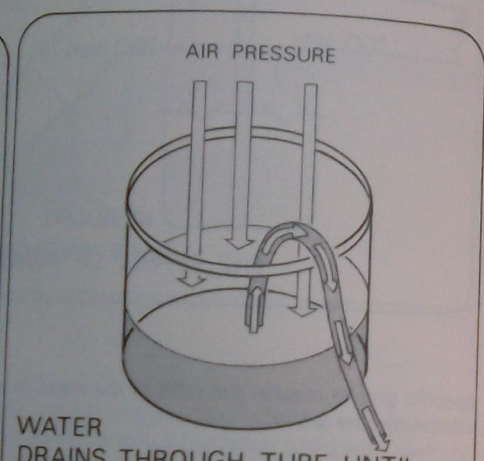
In 2: Lowering of pressure in the tube allows the atmospheric pressure to push the fluid upwards inside the tube.

In 3: Fluid flow is established because of the difference in pressure established between the two legs of the curved tube.

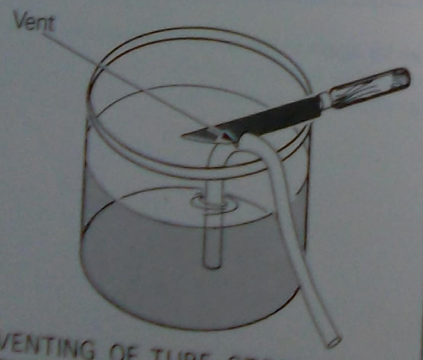
In 4: The flow is halted because air has now been allowed to equalise the pressure on both sides of the tube. The atmospheric pressure acting on the surface of the fluid cannot push the fluid into the pipes against itself. The tube is now 'vented to atmosphere'. The same 'venting' can be obtained by allowing air (atmospheric pressure) at the upper part of the curved tube.



SYPHON ACTION

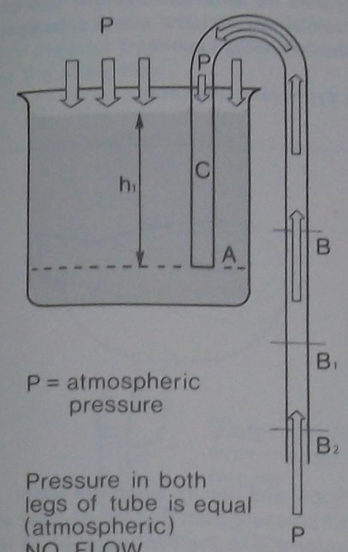


WATER
DRAINS THROUGH TUBE UNTIL
WATER LEVEL REACHES TUBE INLET



VENTING OF TUBE STOPS
SYPHON ACTION

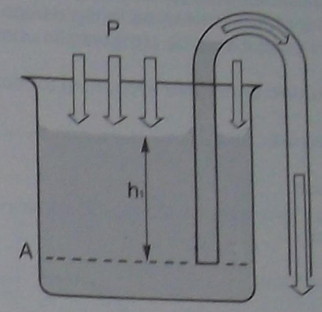
1.



P = atmospheric pressure

Pressure in both legs of tube is equal (atmospheric)
NO FLOW

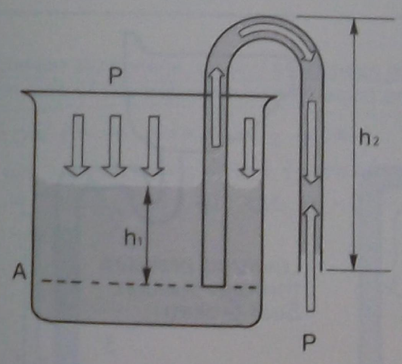
2.



Lowering of pressure in tube allows atmospheric pressure to push liquid up into immersed tube.
Pressure at A:

P + h_1 (height of water column)

3.

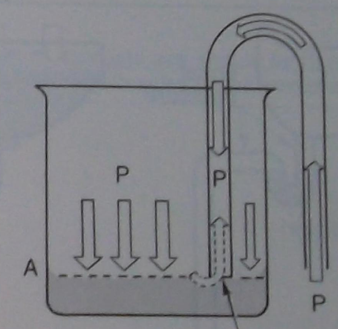


Pressure at left (A): P + h_1

Pressure at right: P − h_2

FLOW from left to right

4.



Pressure side now vented to atmosphere

Pressure left = Pressure right

FLOW STOPS

THE SYPHON PRINCIPLE

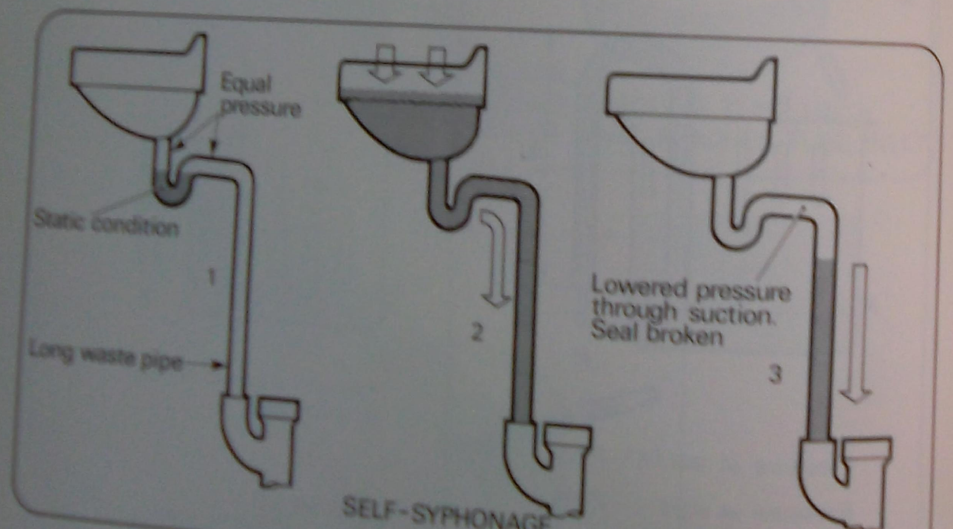
5.6 LOSS OF WATER-SEAL IN TRAPS

There are various ways in which a trap may lose or partially lose its water-seal. This is one of the principal things to be prevented in the design and installation of any soil and waste pipe system. Loss of seal in traps may be attributed to one or more of the following causes:

- syphon action either self-syphoning (direct) or induced syphoning (indirect)
- back pressure
- evaporation
- momentum
- capillary action
- waving out
- pressurised areas

5.6.1 Direct syphonage (self-syphonage)

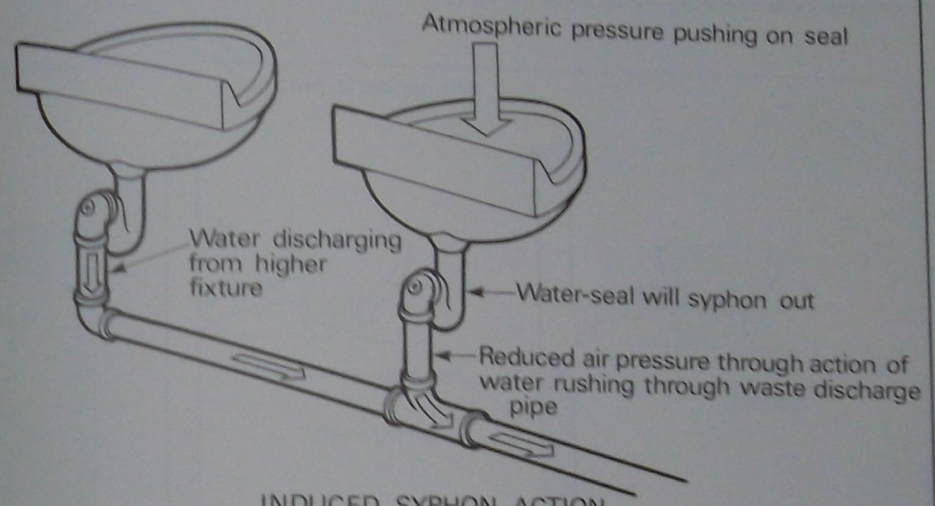
This is one of the most frequent causes of loss of seal in traps, and occurs when the water surface on the outlet side of the trap is subjected to less air pressure than that on its inlet side. This may occur depending on how the pipe is filling with water due to the configuration of the pipework. An example is illustrated where a basin is shown connected by a long waste pipe to a level inlet. In 1, the water-seal is shown intact with an equal air pressure on both sides. If the basin is filled with water and the plug removed, the water will flow through the trap and down the waste pipe as shown in 2, driving the air in the waste pipe before it and causing a reduction in pressure behind. The pressure of the atmosphere on the inlet side of the trap would continue to force the water forward, resulting in a broken seal as shown in 3.



SELF-SYPHONAGE

5.6.2 Indirect syphonage

Syphonage will also occur if two fixtures are connected to the same waste pipe, especially when one is connected at a higher level than the other. A discharge of water from the higher fixture will tend to draw air from the branch pipe as it passes, thus allowing the atmosphere to force the seal out of the lower trap.



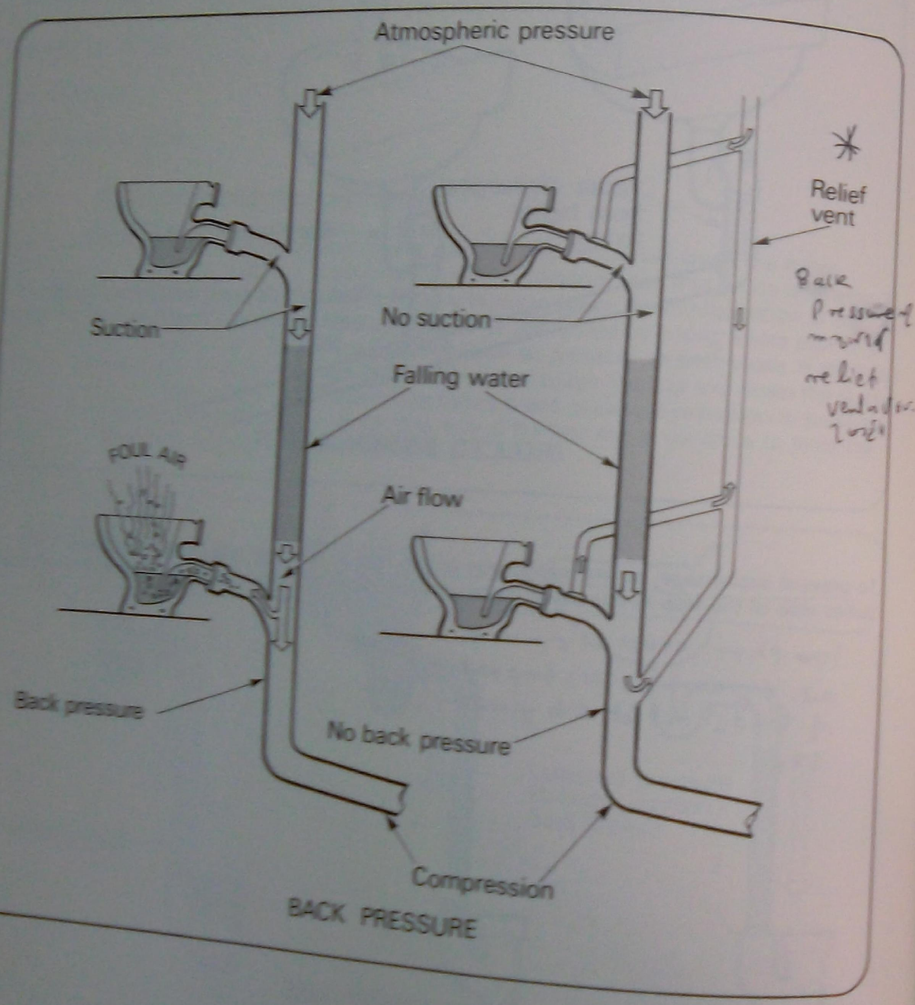
INDUCED SYPHON ACTION

To prevent syphonage, an anti-syphonage or trap vent of adequate size should be fixed on the outlet side of the trap to ensure an equal pressure of air on both sides of the trap seal at all times.

NOTES

5.6.3 Back pressure

A similar action, also closely related to syphonage, can occur through the movement of water in a stack serving fixtures on different floors, as shown below. Loss of water-seal will usually occur in fixtures situated at the base of the stack or near abrupt changes in direction. When discharges from the highest fixture pass down the stack, they tend to compress the air being forced down ahead of them. This pressure is partly relieved by forcing the compressed air through the water-seal of the lower fixture. After such a discharge has passed the branch of this fixture, some of the air in the branch is drawn along with it, creating a reduced pressure on the trap seal. This fluctuation in air pressure imparts a waving motion to the water in the trap and some of it will flow over the outlet, reducing the depth of the trap seal.



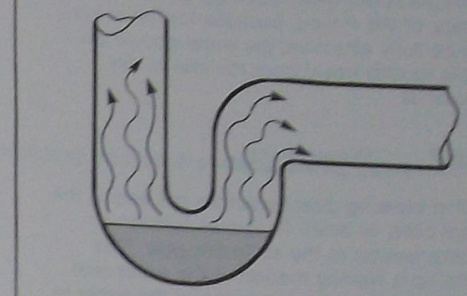
BACK PRESSURE

5.6.4 Evaporation

When fixtures are not used for some time, the water in the trap will gradually evaporate, allowing foul gases to pass through into the building. Except when in a saturated condition, the atmosphere is constantly taking up moisture from any available source, including traps, and unless traps are periodically replenished with water, their seals will be broken. Under normal conditions, it would require some weeks for this to occur; the occasional use of the fixture will eliminate this.

NOTE:

Air-conditioned buildings are more prone to this problem because of their constant temperature. Therefore, it is essential for the water-seal in traps to be replenished regularly.

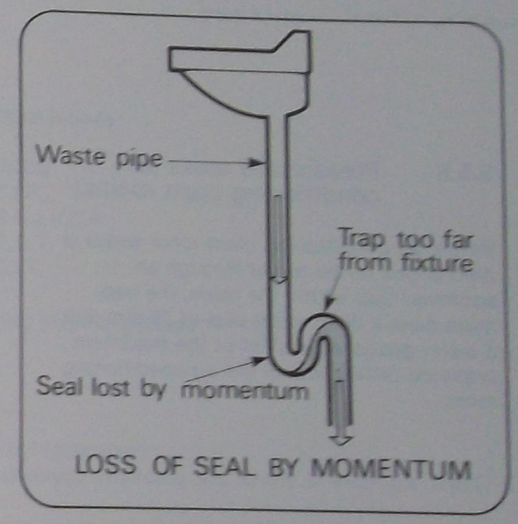


WATER LOSS BY EVAPORATION MAY REDUCE LEVEL IN THE TRAP AND DESTROY THE SEAL

5.6.5 Momentum (Direct syphoning)

Loss of water-seal by momentum will occur when the trap is fitted too far from a fixture, as shown. The discharging water gains such speed and momentum before hitting the trap, that it is carried through and insufficient remains at the end of the discharge to reseal the trap.

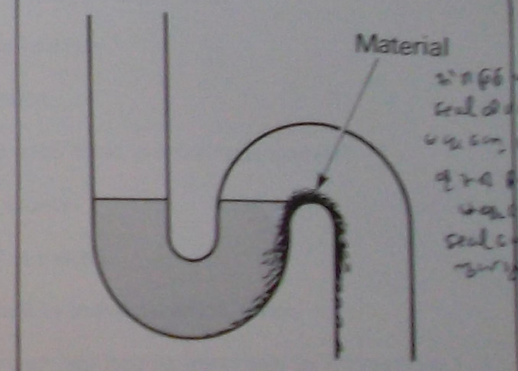
Offensive odours will be discharged into the building when the distance between the fixture and water-seal is excessive. Both odour and loss of seal by momentum can be avoided by placing the trap as near as possible to the fixture and in no case more than 300 mm from the outlet of any urinal or 600 mm from the outlet of any other fixture.



LOSS OF SEAL BY MOMENTUM

5.6.6 Capillary attraction

The water-seal of a trap is occasionally broken through materials of an absorbent nature, such as a small piece of rag, lint or wool, finding its way into the trap and hanging over the outlet, as shown. The water in the trap seal is drawn up the material and over the crown weir by capillarity; the seal is broken fairly rapidly by this means.

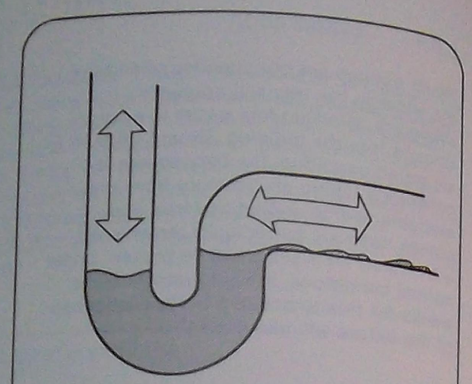


LOSS OF SEAL BY CAPILLARITY

To avoid this problem, smooth-bore traps of a self-cleaning type should be used. The trouble is not likely to occur so readily in traps of the P-type, because for the action to be fully effective, the water should be able to drip freely from the end of the material.

5.6.7 Waving-out

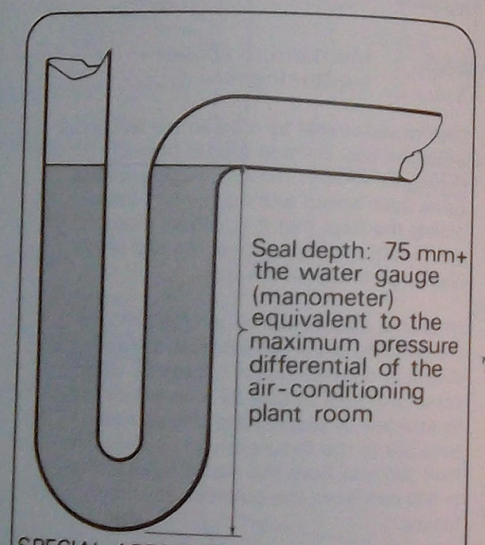
Wind blowing directly across the end of the vent pipe, or down it, causes tension or compression of the air in the pipe. This sets up a waving motion of the water-seal in the trap and causes some of the water to splash over the outlet and run down the waste pipe or the soil pipe, so reducing the level of the seal in the trap.



WIND PRESSURE CAUSES PARTIAL LOSS OF SEAL BY WAVE MOTION

5.6.8 Pressurised areas (air-conditioning plant rooms)

Where air-conditioning plant room waste is discharged to the sewer through an approved trap within the room, the trap must have a deep water-seal of 75 mm plus a water gauge equivalent of the maximum pressure differential of the air-conditioning room.



SPECIAL APPROVED FLOORWASTE GULLY WITH A DEEP SEAL

REVISION QUESTIONS

1. Give one example of each of the following:

   a. Ablutionary fixture
   b. Waste water fixture
   c. Greasy water fixture
   d. Soil fixture

2. Give two examples of tools used in sanitary plumbing from each of the following categories:

   a. Setting
   b. Percussive
   c. Gripping
   d. Forming
   e. Cutting

3. Define each of the following terms:

   a. Fitting
   b. Fixtures
   c. Stack
   d. Upstream vent
   e. Downstream vent

4. Give the full term for each of the following abbreviations:

   a. BT
   b. IO
   c. UPVC
   d. I.C.
   e. S.V.P.
   f. O.R.G.
   g. C.I.P.
   h. R.R.J.V.C.P.
   i. G.D.T.
   j. G.I.T.

5. With sketches, briefly explain how the following pipes are joined:

   a. VC pipes (modern type)
   b. UPVC pipes (small diameter)

6. a. What is cement compo used for and how is it prepared?
   b. What compo mixes are generally used in drainage plumbing and where is each one used?

7. a. When is concrete used in a drainage system and how is it prepared?
   b. What types of mixes are used and where?
   c. What is the purpose of using concrete in drainage installations?

8. Sketch a P-trap, name its parts and explain its function.

9. Sketch a floorwaste gully and explain its function.

10. Where are disconnector gullies and boundary traps fitted in a drainage system?

11. With a sketch, briefly explain the action of a syphon.

12. Sketch a P-trap and show where the trap vent is placed.

13. Explain how the water-seal in a trap may be lost by indirect syphon action.

14. Explain how an incorrectly positioned fixture trap may lose its water-seal by momentum.

15. How is the loss of seal in traps prevented in some stack designs?

6 HOUSE DRAINAGE

6.1 THE SEWERAGE SYSTEM

All fixtures are connected to the sewerage system which is connected in turn to the sewage treatment plant. The whole system comprises 6 components.

- Waste and soil discharge pipes
- House or property drains
- Branch or reticulating sewers
- Main sewers
- Outfall sewer
- Treatment plant

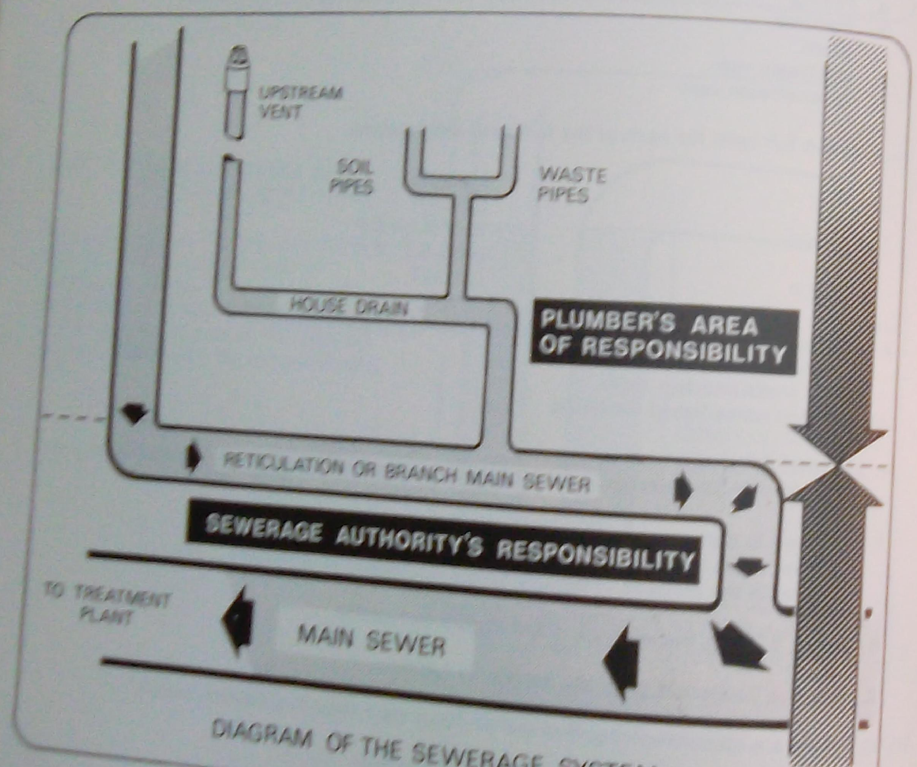


DIAGRAM OF THE SEWERAGE SYSTEM

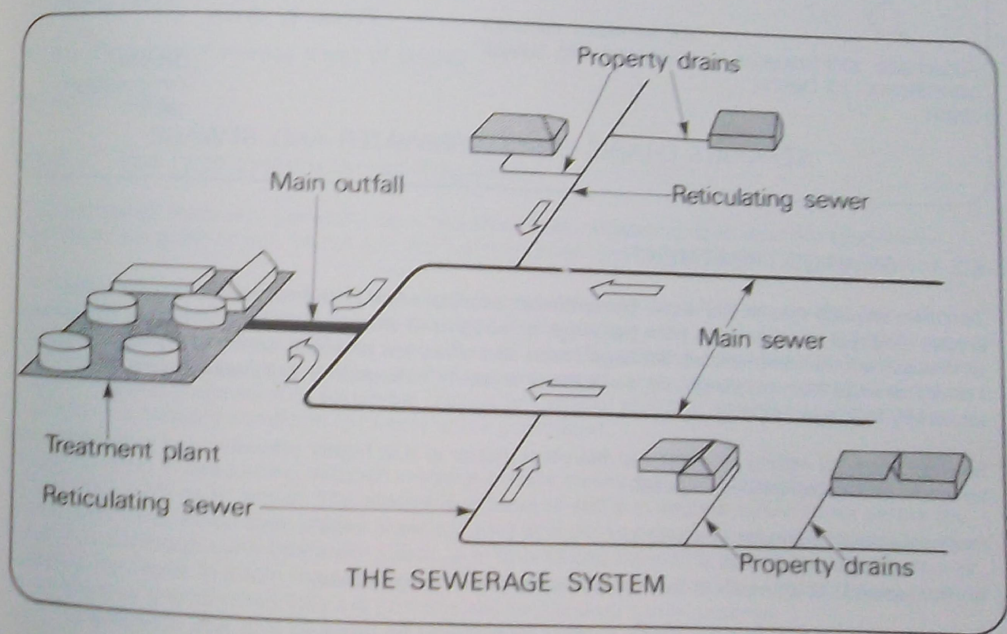
6.2 BRIEF HISTORY OF DRAINAGE

The history of drainage goes back several thousand years with evidence of large systems constructed by the Indus' civilisation of India, the Romans and the Cretans. Drainage pipes made of pottery, rather like those we use today, have been found dating back to about 3000 B.C. Some quite elaborate systems of drainage and plumbing were constructed by the Romans, even to the extent of having water closets with flushing cisterns, but sanitation became almost non-existent again in later periods. During the Middle Ages, and until the nineteenth century, open channels in the streets were the only means of disposal for garbage and soil. It was in the mid-eighteen hundreds that the glazed earthenware pipe was introduced and this made the water carriage system of drainage possible again for the first time since the Roman systems.

6.2.1 Types of drains

There are two general types of sewerage systems in use throughout the world; the 'combined' and the 'separate' systems. The combined system provides one common system of sewers to carry away both foul sewage and stormwater. The separate system provides two separate systems of drains; one for the conveyance of foul sewage only, the other for the removal of rain-water.

Mainly because of economics, the common type of system used in Australia is the separate system. To build a combined system would mean that the pipes and the sewage treatment works would have to be enormous to cope with the extra amount of fluid to be treated during storm conditions, and the cost would be prohibitive.

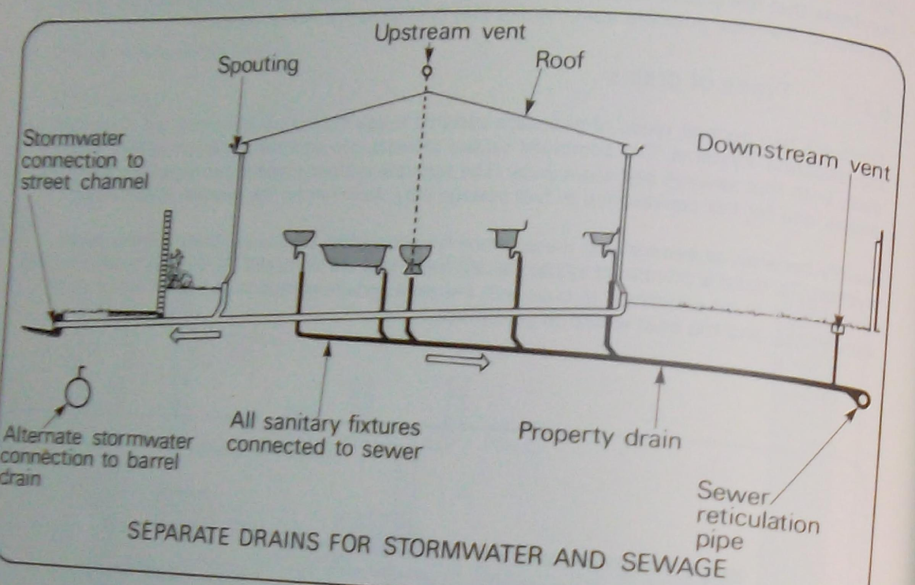


THE SEWERAGE SYSTEM

In Australia, there are two classes of drainage systems:

- Stormwater drains, for the disposal of rain-water.
- Sewer drains, for the disposal of sewage.

Because of this separate system arrangement, it is illegal to discharge rain-water into the sewer drains.



SEPARATE DRAINS FOR STORMWATER AND SEWAGE

6.3 SEWAGE TREATMENT

The term sewage means any water-borne human excreta, urine or domestic waste water. The proper disposal of all sewage from buildings is recognised as essential for combating the spread of disease within communities. All large towns and cities are provided with a sewerage system to convey sewage from buildings, via a system of property, reticulating and main sewers, to a sewerage treatment plant.

Sewage consists mainly of water, but the other matter in it is highly offensive and putrefactive and needs to be treated before disposal.

The process of treatment consists of:

- the removal of as much of the objectionable matter as possible;
- breaking down the objectionable matter which cannot be removed into less offensive or harmless compounds;
- the destruction of harmful bacteria.

Sewage is in a state of decay and is chemically unstable. Fresh sewage contains 2 to 4 parts per million (p.p.m.) of free oxygen and with this oxygen content, certain bacteria (aerobic bacteria) exist and decompose the sewage by using up the available oxygen. This oxygen is used up after about thirty minutes when the sewage is said to be 'stale', after which the aerobic bacteria can no longer operate. The process is then taken over by other bacteria (anaerobic bacteria). These bacteria break down the organic matter into simpler forms, at the same time giving off various gases, e.g., hydrogen sulphide and ammonia, which have characteristic, unpleasant odours. The final step in the breakdown of the sewage is oxidisation (combining with oxygen) of these last organic forms.

Sewerage treatment aims to accelerate this decomposition process by providing suitable conditions for the various processes.

6.3.1 Methods of treating sewage

The methods of treating sewage fall generally into one of six processes, but some treatment plants may combine more than one of these to improve efficiency or to suit local conditions.

The processes are:

- the farm system
- stabilisation ponds
- the activated sludge process
- Imhoff tanks
- the discharge of sewage direct to the sea
- septic tanks

6.3.2 The farm system (broad irrigation)

This method of treatment generally uses two processes, depending upon whether evaporation conditions are good or not. These are: the 'Land filtration' and the 'Grass filtration' processes.

Land filtration is a process which uses carefully prepared pastures which are divided into smaller sections of low check banks. After being graded they are sown with grass, then filled with sewage effluent to a depth of about 100 mm every 18 to 20 days. Evaporation takes place but a portion of the liquid is purified by filtering through the soil and is then carried away by underground drains to rivers or creeks. Some form of rotational grazing by cattle or sheep is necessary to keep these pastures in a suitable condition for waste water purification.

Grass filtration is used when reduced evaporation rate makes the land filtration method impractical, such as in winter. The sludge is allowed to settle in sedimentation tanks before the waste water is directed over graded areas covered with dense grass and natural herbage. As this water flows through such treatment plants, it is filtered and the plants absorb the organic matter enabling the liquid to attain the required standard of purity on reaching the drains. These grassed areas are only grazed when they are not required for the purification process.

An example of the farm system is the M.M.B.W. area at Werribee. However, that system is also supported by stabilisation ponds to handle excess sewage.

6.3.3 Stabilisation ponds

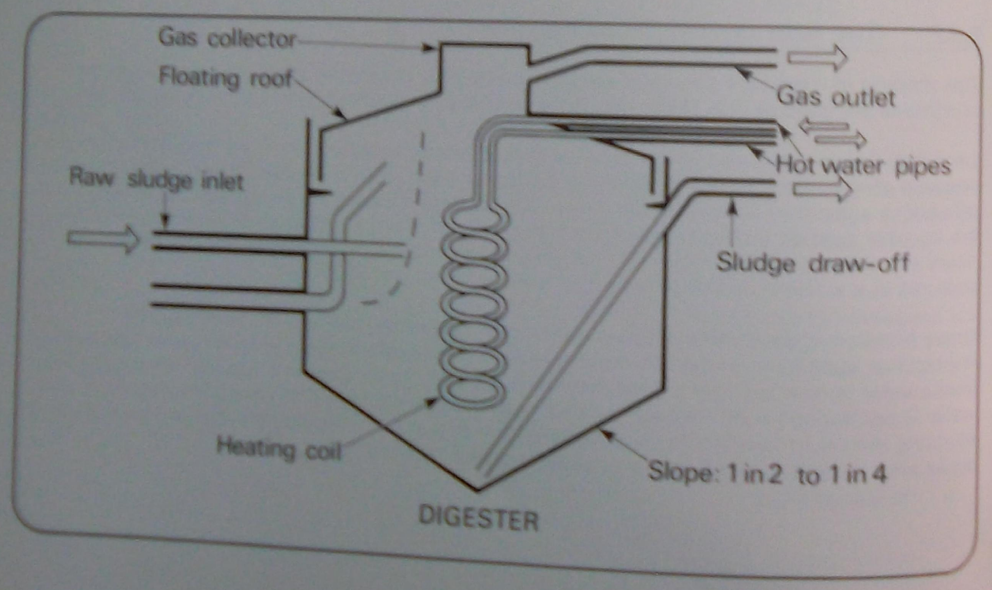
These are also known as 'Lagoons' or 'Oxidisation ponds'. This method of treatment is coming into increasing use, especially in country areas where large areas of land can be obtained at relatively low cost. The sewage is held in lagoons, or ponds, usually of about 2 hectares in area and between 1 metre and 2 metres deep. Algae thrive on the nutrients in the sewage, and by the action of sunlight, produce oxygen which enables aerobic bacteria to decompose the sewage at a rapid rate. A number of ponds, arranged in series, is often used, and as the sewage flows through these, the suspended solids and Biochemical Oxygen Demand (B.O.D.) are progressively reduced through each pond.

6.3.4 The activated sludge process

The treatment of sewage by this process is done in two stages:

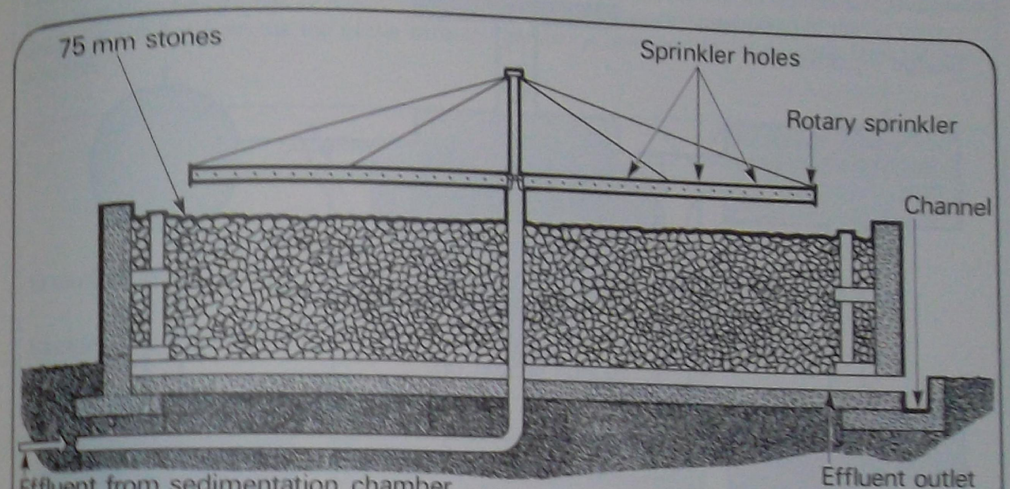
- the removal of suspended solids (called sludge) by sedimentation;
- the treatment of effluent from the sedimentation tank.

The sewage is allowed to stand in, or to flow very slowly through, a settling tank so that the suspended material falls towards the bottom of the tank. About 60% of suspended solids are usually removed in this way. This sludge is carried to a sludge digester where anaerobic bacteria change it into matter which, when dried, may be burnt, used as filling, or as a low-grade fertiliser. Heating coils may be incorporated in the sludge digester to maintain the sludge as closely as possible at 33°C, which is the temperature at which the anaerobic bacteria operate most efficiently. Gases given off in the digestion process are inflammable and may be collected and used as fuel to provide the necessary heating.



DIGESTER

To treat the settling tank effluent, liquid is taken from the top of the chamber and passed through a trickling filter. This is a tank containing a bed of coarse stones over which the effluent trickles. A gel, consisting of aerobic bacteria and other low forms of life, forms over the stone surface. The bacteria feed on the sewage in the presence of the air among the stones and add oxygen to it, breaking down the organic material. Large trickling filters are usually circular and the effluent is sprayed over the top surface by a rotary sprinkler.

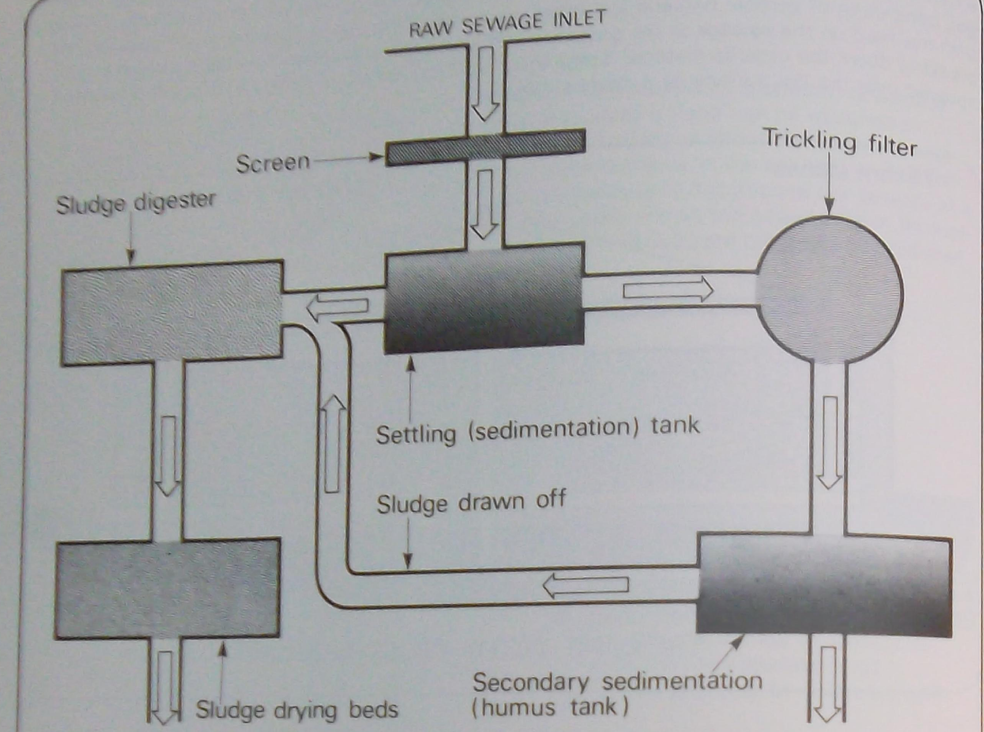


TRICKLING FILTER CROSS-SECTION

The effluent from the outlet of the trickling filter is taken to a secondary sedimentation chamber (humus tank), where any remaining suspended material settles out. The sludge from the bottom of the humus tank is periodically pumped back to the sludge digester. The final effluent from the humus tank may be passed through a sand filter, or disposed of directly into a river or lake, or by irrigation, and being chlorinated before disposal if contamination of bathing or drinking water is likely to occur.

An example of this type of treatment is the M.M.B.W.'s South Eastern purification plant at Carrum.

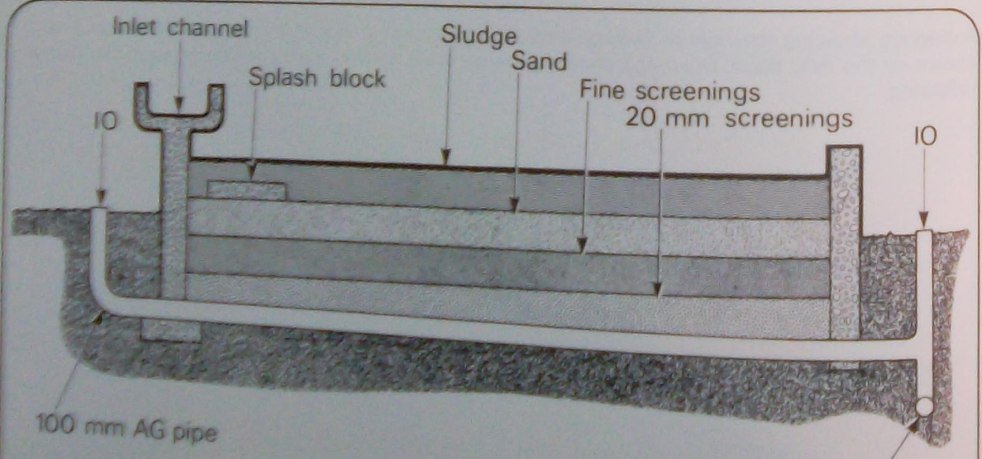
A diagram showing the flow of sewage through a treatment works of the type outlined above is shown on the next page. Drawings showing the separate components are also given in the pages following.



DISPOSAL OF SLUDGE (INCINERATOR OR LANDFILL OR FERTILISER)

FINAL EFFLUENT DISPOSAL TO LAKE OR STREAM OR BY IRRIGATION. CHLORINATION MAY BE NECESSARY

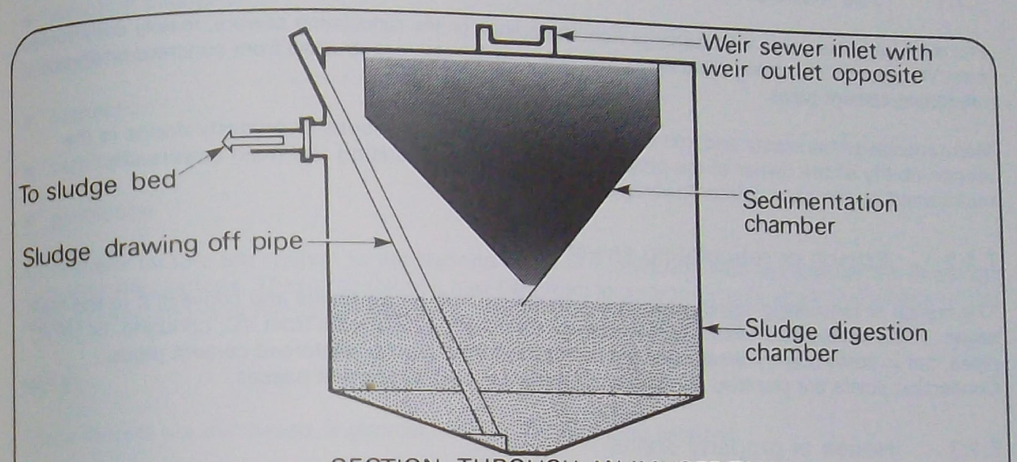
DIAGRAM OF A SEWAGE TREATMENT WORKS



SLUDGE DRYING BEDS

6.3.5 Imhoff tanks

This is an installation which has been used often for smaller community sewerage systems. The economical limit of capacity is for about 10 000 population. The Imhoff tank combines the sedimentation chamber and sludge digester in one unit. The upper part of the tank serves as the sedimentation chamber and is fitted with a bottom which slopes towards a central slot. The settled sludge falls through this slot into the lower compartment which forms the sludge digester. After digestion, the sludge is drawn off from the bottom of the tank and taken to drying beds, while the effluent from the top of the settling chamber is conveyed to the trickling filter for aeration.



SECTION THROUGH AN IMHOFF TANK

6.3.6 Discharge of sewage directly into the sea

Where sewage can be discharged directly into the ocean, no treatment is usually necessary. It is essential that at the point of discharge, ocean tides and currents be such as to carry the sewage out to sea and not sweep it back on to beaches.

The oxidisation of the sewage is accomplished by the oxygen dissolved in water.

6.3.7 Septic tanks

The septic tank is in effect a small sewage treatment plant. Though septic tanks are usually installed to deal with water closet wastes only, they are satisfactory for disposal of all household wastes, provided a grease trap is installed to prevent kitchen grease from clogging the pipes.

Sedimentation and sludge digestion is provided in the tank and aeration of the effluent is accomplished in the absorption drains.

Septic tanks are dealt with in greater detail in a separate section of Manual '10-4 Connection Systems & Special Disposal'.

7 SEWERS AND DRAINS

7.1 OUTFALL SEWER

The outfall sewer may be constructed from ceramic, concrete, or fibrous reinforced cement pipes, but where the flow rate is high, it may consist of a covered or an open concrete channel which takes sewage to the treatment plant from the main sewers in the larger metropolitan areas. However, in the smaller areas, the main sewer can flow directly to the treatment plants.

7.1.1 The main sewer

The main sewer receives the discharge from the branch or the reticulating sewers, mainly constructed from VC pipes in the metropolitan areas, but they may be also constructed from concrete or fibrous reinforced cement pipes.

Maintenance of the waste and soil discharge pipes and of the house or property drains is the responsibility of the owner of the property. The branch, reticulating and main sewers are maintained by the appropriate Sewerage Authority.

7.1.2 Branch or reticulating sewer

The branch or reticulating sewer receives the discharge from house drains and conveys it to the main sewer. In the metropolitan areas, branch sewers are usually constructed from VC, concrete, or UPVC pipes, but in some country areas, they are constructed from fibrous reinforced cement pipes. Connection points are provided on the branch sewer for each property it passes.

7.1.3 House or property drains

The house or property drain receives the discharge from all the soil and waste fixtures associated with a single property and conveys it to the branch sewer.

The connection between the house drain and the branch, or reticulating sewer, is usually made at, or near the boundary of the property. House, or property drains may be constructed from VC, cast iron or UPVC pipes and fittings or combinations of these materials. This type of construction applies mainly to large metropolitan areas. However, in some States and areas of such States, they may be constructed from fibrous reinforced cement. The diameter of the pipes will usually be 100 mm for domestic dwellings and 150 mm for large factories or blocks of flats. In some States, they use 125 mm for both, depending on the amount of fixture units being served.

7.1.4 Waste and soil discharge pipes

Waste and soil pipes connect the fixtures in a building with the house or property drains. The diameter of these pipes is determined by the volume of the discharge from the associated fixtures. Local Sewerage Authorities, in conjunction with the National Code, detail the size of pipes to be used. Various pipe materials are used, but in modern constructions, UPVC predominates.

7.2 CONSTRUCTION OF HOUSE OR PROPERTY DRAINS

The following factors must be taken into consideration in the construction of house or property drains.

- design
- interception and disconnection
- gradient (fall)
- direction changes
- branches
- inspection
- ventilation
- protection

All of these factors are subject to the National Code in conjunction with the appropriate Sewerage Authority Regulations. These regulations may vary from locality to locality and a knowledge of the relevant regulations is necessary during the planning of the drainage system.

NOTE:

These factors are discussed in general terms in the following sections.

7.2.1 Design

The house or property drains must be designed to convey the discharge from the soil and waste fixtures to the sewer quickly and by the most direct route. To some extent, the actual route chosen will be dictated by other factors.

Plans

The drainage plan for a property may be prepared by the Sewerage Authority or, in some cases, by the licensed plumber and also by plumbing consultants or private firms employing designers. The plan will show the location and depth of existing and proposed drains and the details of the necessary fittings and pipe sizes.

Line of drains

The house or property drains should be laid in as straight a line as possible with the best possible grade to comply with the National Code and the Sewerage Authority Regulations. This will reduce the possibility of silt deposits and facilitate cleaning in the event of blockage.

Footings

Where the plan requires a drain to be laid parallel to any building wall footings, the drain should be placed as far away as possible from these footings. This is particularly important when the depth of the drain is greater than the depth of the wall footings which may be rendered unstable by the drain excavation.

Traps

The drainage design must include allowance for an overflow relief gully on each separate property and it must be fitted with a loose or 'pop-up' grate.

Reflux valve

A reflux valve must be installed where the overflow relief gully cannot be provided in accordance with Section 3.13 of the National Code, or where specified by the governing Authority.

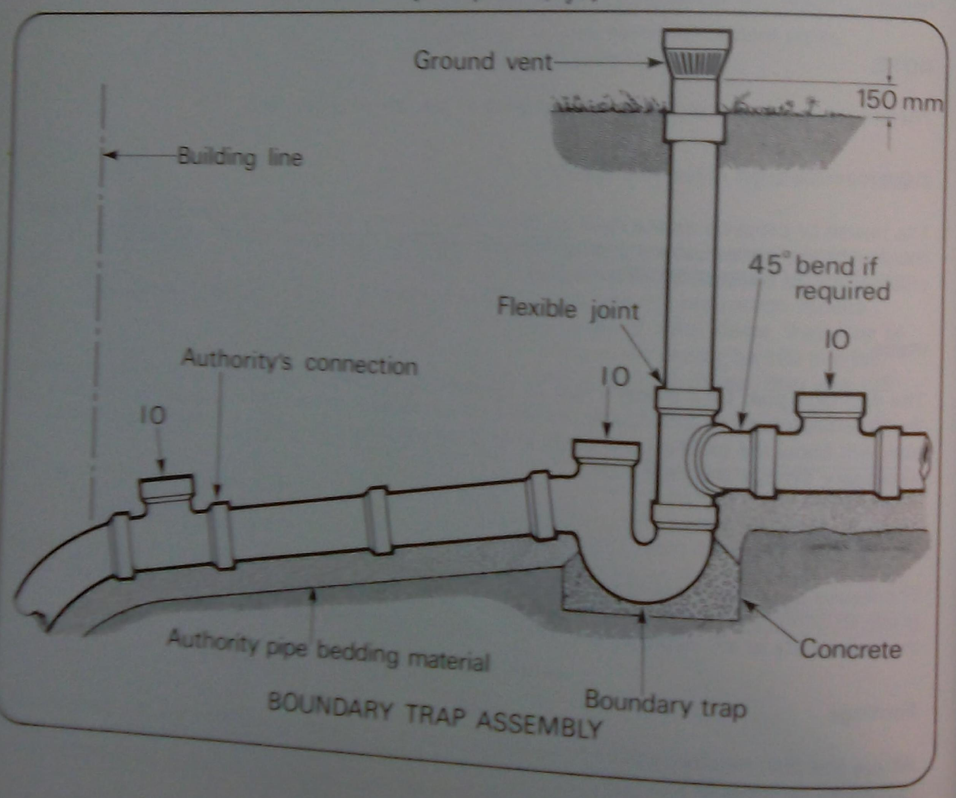
NOTE:

Each property must have a separate drainage system, unless permission for the use of a combined drain by one or more properties is obtained from the Sewerage Authority.

7.2.2 Interception and disconnection

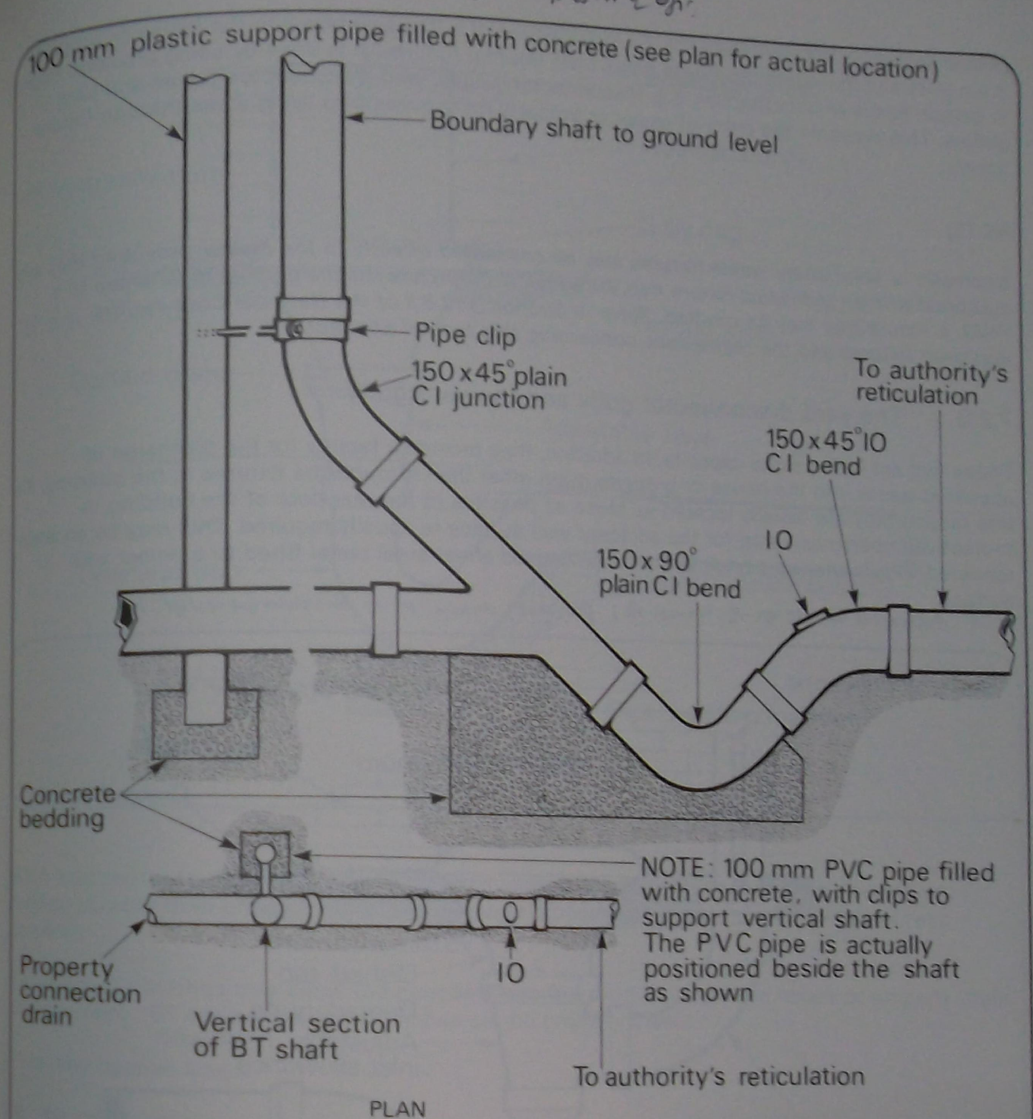
By interception is meant the isolation of the house or property drain from the branch sewer (or relic) by means of a trap seal, usually called a boundary trap (BT) which prevents sewer gases from entering the house or property drains.

Boundary Trap arrangement.



BOUNDARY TRAP ASSEMBLY

Boundary Trap arrangement.



NO-LOSS PREFABRICATED BOUNDARY TRAP

NOTES

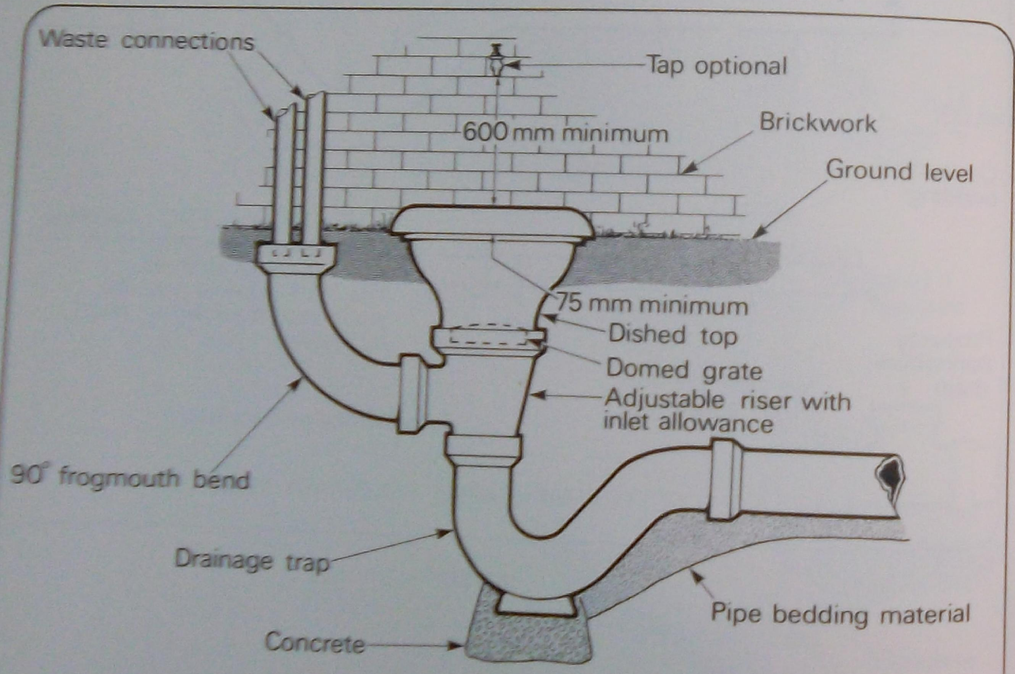
Disconnection is the term used for the arrangement of a trap seal between the house or property drain inlet and the waste discharge pipes from internal fixtures. It is done by using drainage traps in certain forms of construction, e.g. disconnector gullies, yard disconnector gullies and yard gullies. This prevents the entry of sewer or property drain gases into living areas through fixture traps.

NOTE:

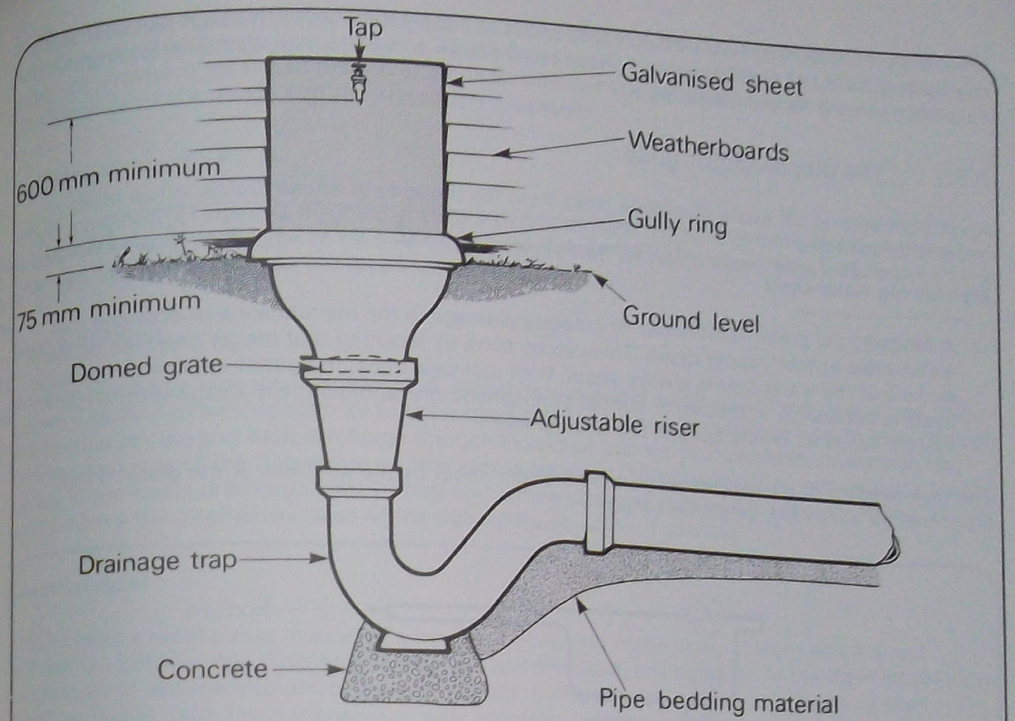
Domestic or ablutionary waste fixtures may be connected directly to the drains, providing they are equipped with an individual fixture trap. However, if the fixture discharge pipe discharges to a FWG, a fixture trap may be omitted. Refer to Section 3.13.8.3 of the National Code for the approved fixtures and the regulations concerning this type of connections.

7.2.3 The yard disconnector gully and the yard gully

These two act in the same capacity. In addition, they provide a facility for the discharge of approved waste into the house or property drain other than through the fixtures in the building. For this reason they are usually located as close as possible to the rear door of the building. A protective impervious apron for the adjacent wall surface is usually required. This may be an area rendered with mortar on a brick wall or a galvanised sheet steel panel fitted to a timber wall surface.



YARD DISCONNECTOR GULLY



YARD GULLY

Both interceptor traps (BT) and drainage traps used in disconnector assemblies also prevent foreign objects from entering either the house or property drain system, or the main or retic sewers.

Sewerage Authorities may allow the boundary trap to be omitted between house or property drain and the retic. 'BT omitted' is then stamped on the property plan.

This may happen when:

- the design of the sewerage system is such that rapid conveyance of sewage to the disposal area takes place;
- through proper and adequate venting of house or property drains, sewer gases can escape harmlessly.

Such a system has the disadvantage that foreign objects may find their way into the branch or reticulation sewer and create blockages which may inconvenience a large number of properties connected to it.

7.2.4 The boundary trap

When installed, it is usually located:

- close to and within the boundary of the property where this is possible;
- at the lowest practicable level so that it can serve the longest possible length of drain.

A ground vent or downstream vent is placed at the boundary trap, which, through its cover and shaft (when the BT is well below the surface level) allows access to it as well as providing the necessary venting for the house drain.

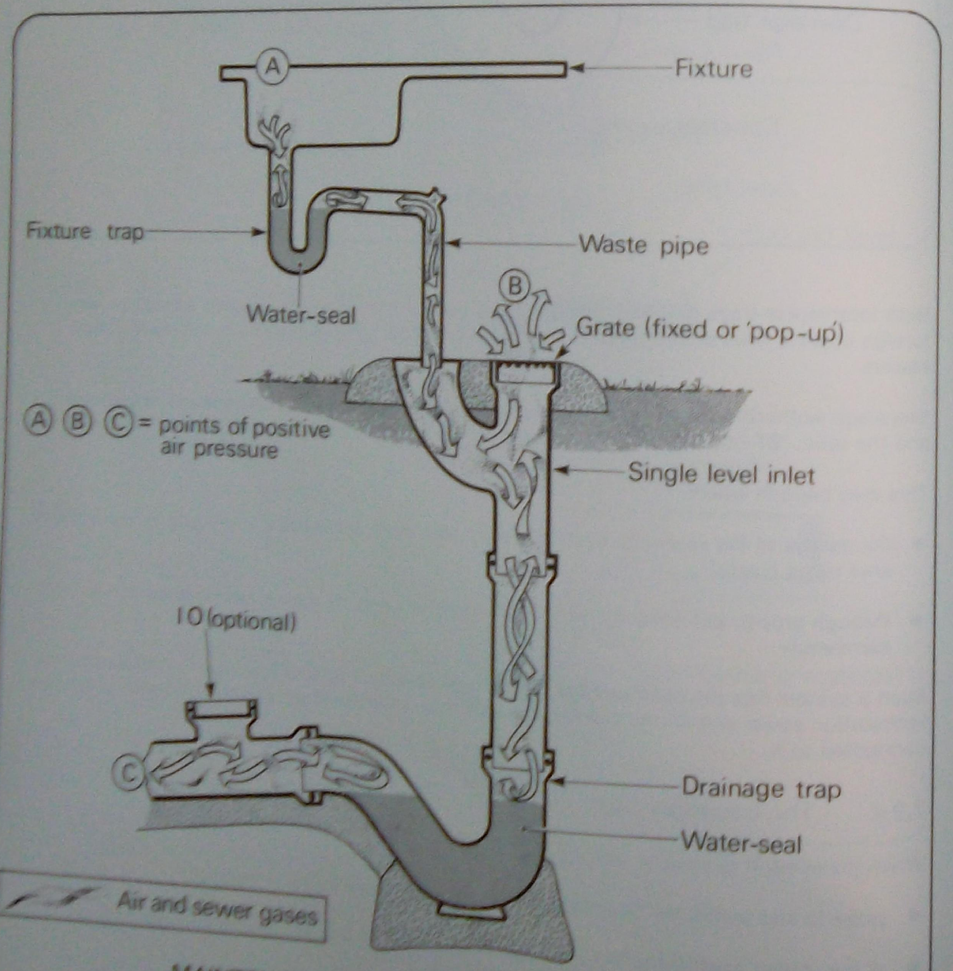
7.2.5 The disconnector gully

Apart from sealing off waste discharge pipes from the property or house drains, it has other important functions.

Maintaining water-seals

— A fundamental principle of house or property drainage is the maintenance of drainage trap water-seals at their proper depth. This can be done by ensuring that the air pressure on each surface of the water-seal is always equal. With drainage traps, the outlet surface of the water-seals is constantly subjected to normal atmospheric pressure as the drainage ventilation system keeps all drains open to the atmosphere.

The maintenance of a balanced pressure is brought about by the air break at the grate of the disconnector assembly, as shown below.



MAINTENANCE OF BALANCED AIR PRESSURE

Fixture traps are open to the atmosphere at the inlet surface of the seal and are subjected to the normal atmospheric pressure of 100 kPa. To allow the outlet surface to be subject to the same pressure, provision for the admission of air under atmospheric pressure is made where waste discharge pipes discharge into the disconnector assembly.

Relieving air pressure

When a quantity of water is discharged from a fixture through a discharge pipe, the air in the pipe is pushed forward and replaced by water. This compressed air would disturb the water-seals of the drainage traps, unless steps are taken to relieve it, as shown.

Foot ventilation

A waste discharge pipe discharges to the atmosphere over the water-seal of a drainage trap. This allows a current of atmospheric air to enter the discharge pipe at its outlet or foot, to pass through the discharge pipe and then discharge through individual trap vents, if provided, or through the downstream side of the trap where no trap vent is provided. This current of air removes any foul gases in the waste discharge pipe, or trap vent where provided, makes any adherent matter friable and oxidises the internal surfaces of the pipes through which it passes.

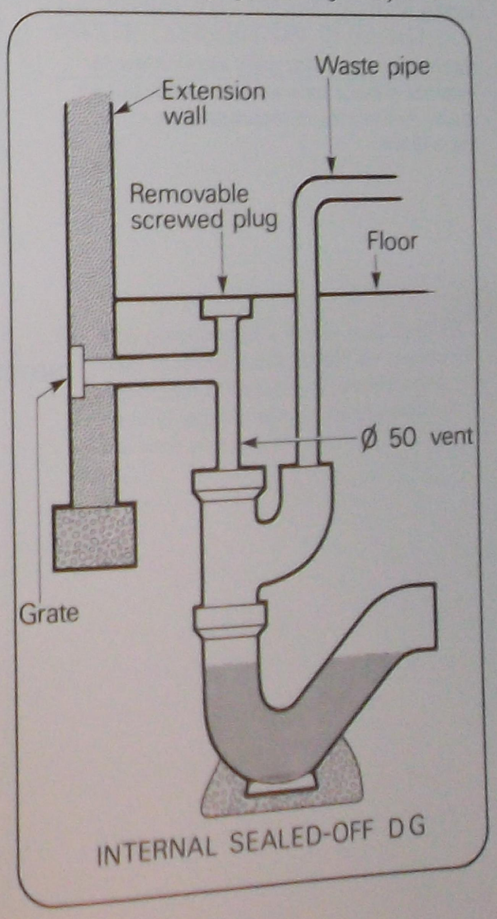
Overflow relief

This acts as a relief outlet in case of a blockage occurring in the drain. If there was a direct connection between the discharge waste pipe and the drain, any blockage in the drain would allow backing-up of sewage into discharge waste pipes, soil discharge pipes and fixtures, or even overflow inside. With the disconnector gully assembly, which is usually installed externally, the overflow takes place outside and through the air break. The latter serves as an inspection opening as well, and can be used when clearing a blockage by means of 'plunging', 'rodding' or by other mechanical means.

7.3 SEALED DISCONNECTOR GULLIES

When building extensions are carried out, they may extend over an existing disconnector gully and permission may be given by the appropriate Authority to retain it in its present location rather than to carry out extensive and costly alterations to the drainage system or to the structure of the building.

Because the riser pipe, through its grate, provides for foot and drainage ventilation, it cannot be left as is under the floor of buildings for obvious reasons. The DG must be sealed off and its ventilation redirected to where it is harmless. This can be done in a number of approved ways, but whatever way is chosen or possible in the circumstances, the riser pipe grating is always sealed off. This is done as shown.



INTERNAL SEALED-OFF DG