UNIT 4 WATER DISTRIBUTION SYSTEM

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4.1 INTRODUCTION

The basic purpose of water distribution system is to provide wholesome water to the consumers as per their need at adequate pressure. It mainly consists of *pipe line* for carrying water from source to treatment plant and leading water from treatment plant to the area of consumption; *valves* for controlling flow in pipe; *fire hydrants* for tapping additional water during fire; *water meter* for measuring discharges; pumps for lifting water into distribution pipes; and *service connection* for bringing water to individual houses. It has been estimated that water distribution system usually accounts for 40% to 70% of the total capital costs of the water supply system. Therefore, its proper and economical design is essential.

In this unit, we shall discuss about various components of water distribution system used for carrying water from source to consumers.

Objectives

After studying this unit, you should be able to

- identify various type of pipes used for conveyance of water and joints connecting the pipes,
- explain the testing procedure of pipeline before allowing water through it,
- explain various types of layout of water distribution system, and
- describe various appurtenances used in house water connection.

4.2 TYPE OF PIPES

Based on construction material, pipes can be broadly classified as under:

(a) Metal Pipes.

(b) Cement Concrete pipes.

(c) Plastic Pipes.

4.2.1 Metal Pipes

Metal pipes can be classified as cast-iron pipes, steel pipes, wrought iron pipes and copper pipes.

Cast-iron Pipes

Cast-iron pipes are most extensively used for the conveyance of water in water supply system due to their durability, strength, resistance to corrosion, ease in laying and simplicity in repairs and maintenance. These are joined by either bell and spigot joint, expansion joint or by flanged joint. There are two types of cast-iron pipes :

(a) Vertically cast pipes.

(b) Centrifugally cast pipes, popularly known as spun iron pipes.

Vertically cast pipes are heavy in weight and low in tensile strength but are used because of good durability. These are available in large diameter. Now this type of pipe is being replaced by spun iron pipes which are thinner and lighter in weight. Spun pipe has smoother inner surface, improved metal quality. Further, these pipes can be made longer in length. Spun pipes are available from 80 mm to 1050 mm diameter.

The usual life of cast iron pipes are about 100 year under normal circumstances.

Steel Pipes

Steel pipes are generally used for pipes having diameter greater than 1200 mm. Large size steel pipes are made from steel plate made to circular form. The edges of the plate are either lap welded or butt welded. Lap welded pipe is re-heated and re-rolled so that the wall thickness becomes uniform.

Smaller sized pipes are made from billet bars or ingots of hot steel. The ingots are pierced and rolled into a cylinder of the required dimensions. Such pipes are known as seamless pipes. These pipes are usually 9 to 10 m long.

These pipes get rusted quickly which reduces their life as well as carrying capacity. To protect pipe from rusting these are provided with inside and outside coating with bitumen. Such pipes cannot sustain high negative pressure that might develop under certain conditions. To protect steel pipes from negative pressure their shells are coated from inside and outside with 1 : 2 cement mortar (popularly known as Hume pipe). Hume pipes combine the advantage of steel (being strong in tension) and those of concrete (being strong in compression). Life of steel pipes is generally taken as 100 years under ordinary conditions.

Wrought Iron Pipes

Pipes of wrought iron are lighter than cast iron pipes and are easily cut, threaded and worked. Pipes are manufactured by rolling flat plates of the metal to the required diameter and the edges being welded. For protection against corrosion, they are galvanised with zinc coating and are known as "galvanised iron pipes". Due to easy workability, they are used for water distribution lines inside buildings. These are found to be costlier and less durable as compared to cast iron pipes.

Copper Pipes

Copper pipes are manufactured in smaller diameter. These pipes are although costly but used in acidic and alkaline environments as they are highly resistant to acids and alkalis. As they can be bent easily and do not sag due to heat, they are used for carrying hot water inside buildings and factories.

Corrosion of Pipes

Water, while flowing through metallic pipes, reacts chemically with the surface of pipe and thereby causing loss of material. The phenomenon of continuous disintegration of metal pipe due to action of water is known as corrosion. In water supply system, corrosion not only causes significant loss in carrying capacity of pipe but also reduces life of pipe and joints. Corrosion also makes water unpalatable by imparting impurities like colour and odour etc. The corrosion of metallic pipe due to water logged soil above the pipe is termed as external corrosion while corrosion due to water flowing or contained in pipe termed as internal corrosion.

Mechanism of Corrosion

The mechanism of corrosion in pipes can be understood with the following example of iron pipes. When iron comes into contact with electrolyte water, it has a tendency to ionize and go into solution.

$$Fe + 2H^{+} \rightarrow Fe^{++}$$

Fe^{++} ions combine with hydroxide ions (OH^{-}) to form ferrous hydroxide ($Fe(OH)_2$)

$$Fe^{++} + 2OH^{-} \rightarrow Fe(OH)_2$$

The ferrous hydroxide so formed reacts with dissolved oxygen to form ferric hydroxide ($Fe(OH)_3$), which get deposited to the surface of pipe.

Deposition increases the roughness of pipe and ultimately decreases its carrying capacity.

$$2Fe(OH)_2 + O_2 + H_2O \rightarrow 2Fe(OH)_3$$

Factors Affecting Corrosion of Pipes

The mineral content, dissolved oxygen level and pH of water influence corrosion rate of metallic pipe. Presence of carbonic and other acids, free chlorine and dissolved oxygen level increases the corrosion in pipes, while water possessing sufficient calcium carbonate alkalinity is anti-corrosive in nature. Micro-organisms such as sulphate-reducing or iron bacteria also cause corrosion.

Corrosion in boilers is controlled by removal of the oxygen from the feeding water by deaeration, and by the reaction of residual oxygen with sodium sulphite or hydrazine. It is also controlled by application of alkaline chemicals such as caustic soda and sodium phosphates to provide boiler water pH in the range of 10-12.

Inhibition of corrosion in cooling towers is provided by the application of corrosion inhibitors such as chromates, phosphates and silicates applied singly or in various combinations. Development of a thin protective layer of calcium carbonate on the metal surfaces is effective for preventing corrosion of the metal in the water distribution system.

4.2.2 Cement Concrete Pipes

Cement concrete pipes can be divided into four categories as listed and described below.

(a) Plain cement concrete pipes.

(b) Reinforced cement concrete pipes.

(c) Pre-stressed concrete pipes.

(d) Glass fibre reinforced concrete pipes.

Plane Cement Concrete Pipes

Plain cement concrete pipes are manufactured in smaller sizes up to the maximum diameter of 600 mm and used for low heads (up to 15 meter).

Reinforced Cement Concrete Pipes

RCC cylinder pipes are similar to pre-stressed concrete pipes except that in place of high tensile steel wire mild steel rods are used as circumferential reinforcement. The rod is wound spirally under tension onto a rotating metal cylinder and being welded to the cylinder at both ends. The reinforced cylinder is then covered internally and externally with concrete. The internal lining is spun and external coating applied by impact and smoothed in layers. For designing, both the core steel cylinder and the reinforcement are assumed to resist hoop stresses. They are available in diameters from
200 mm to 1800 mm. They are mostly used as water mains.

Pre-stressed Concrete Pipes

They are made by tensioning high tensile wire wound spirally around cylindrical core. The core consist of either concrete which is pre-stressed longitudinally or of a thin steel cylinder which has a thick spun concrete lining to the interior.

The main advantage of pre-stressed concrete pipes is that they are found to be cheaper than other pipes above 300 mm diameter at higher pressures. By increasing the number of turns of pre-stressing wires, they can be made to stand higher pressure. They are corrosion resistant. Disadvantages with such pipes are that they have got very limited flexibility and sometimes external lining to protect the pre-stressing wires get cracks when subjected to internal water pressure.

Glass Fibre Reinforced Concrete Pipes

They are relatively new product. Alkali-resistant glass fibres are used as circumferential reinforcement placed near the outer and inner surfaces of the pipe wall. The reinforcement is stronger than ordinary steel and are more resistant to the normal corrosion agencies, hence lesser pipe thickness is required.

4.2.3 Plastic Pipes

Following types of plastic pipes are used in water works for water supplies :

(a) Unplasticised polyvinyl chloride (UPVC) pipes.

(b) Polyethylene pipes.

(c) Glass reinforced plastic (GRP) pipes.

Unplasticised Polyvinyl Chloride (UPVC) Pipes

UPVC pipes are in use for water distribution system in sizes ranging from 15 to 150 mm in diameter and occasionally upto 350 mm. They are rigid, light, in 6 or 9 m lengths, with socket and spigot joints either for sue with solvent cement or a rubber ring. The pipes are composed of polyvinyl chloride plus necessary additives for getting surface finish and mechanical strength. They do not have detrimental effect on the composition of water passing through them. The main advantage of UPVC pipes is its resistance to corrosion. But UPVC pipes have not been found fully satisfactory in use, especially in the larger diameters above 200 mm. Lightness and resistant to wide range of chemicals, fungi, bacterial corrosive agents are its main advantages. Due to the elastic property, they can withstand deformation resulting from earth shock movements. But they are not suitable for hot water supply.

Polyethylene Pipes

Polyethylene is a thermoplastic material, which softens with heat. In its natural state, it is translucent but when used for pipes a black or blue pigment is added to reduce the degrading effect of ultraviolet light. They are light in weight and flexible, resistant to abrasion and corrosion and have better impact resistance at low temperatures than UPVC pipes.

Two types of polyethylene pipes are available for water supply purpose. These are

- low density polyethylene (LDPE) pipes, and
- high density polyethylene (HDPE) pipes.

Low Density Polyethylene (LDPE) Pipes

Low density polyethylene (LDPE) pipes are flexible and made upto 60 mm diameter coils of length 25, 50, 100, 150 and 200 m.

High Density Polyethylene (*HDPE*) *Pipes*

High density polyethylene (HDPE) pipes are harder than LDPE pipes. They are of larger diameters ranging from 300 mm to 3000 mm internal diameters. Larger diameter HDPE pipes are manufactured by a helical winding process and are known as spiral pipes. They have higher resistant to impact than LDPE pipes. Other advantages and disadvantages are similar as LDPE pipes.

Glass Reinforced Plastic (GRP) Pipes

GRP pipes are corrosion resistant, have smooth surface and high strength to weight ratio. These pipes can resist external and internal corrosion where the corrosion mechanism is galvanic or chemical in nature. They are manufactured of epoxy resins reinforced with glass fibres. The fibres comprise either of continuous filaments wound onto the pipe as it is formed to create a cross ply of reinforcement or may comprise of chopped strands mixed in the resin. Sometimes, they are centrifugally casted but more frequently they are made progressively on a rotating mandrel. The pipe of bigger diameters and thickness comprise of layers of different resins or layer being cured before next is applied. Smaller diameter pipes are mostly made from one type of resin throughout. The resins are thermosetting, plastics, which soften on heating but become irreversibly hard with chemical change while cooling. Joints can be socket and spigot with O-ring synthetic rubber rings or push in gaskets. Pipes are also rigid jointed using a resin adhesive.

Selection of Pipe Material

Pipe material are selected mainly on the following criteria :

- durability and life of the pipe,
- pipe cost,
- installation and maintenance cost,
- availability, and
- Suitability under specific conditions.

4.3 JOINTS IN WATER SUPPLY PIPES

Joints used for connecting water main or sub-main may be classified as:

- spigot and socket joint,
- flanged joint,
- expansion joint, and
- collared joint.

4.3.1 Spigot and Socket Joint

The joint is also called bell and spigot joint. The enlarged end is called ‘socket’ or ‘bell’ whereas the normal end is called spigot. The normal end, i.e. spigot is fitted into the socket and proper alignment is done. The joint is made by caulking in spun yarn (jute) and then filling the remainder of the joint space by molten lead and then thoroughly caulking the lead. The molten lead solidifies quickly and makes the joint water tight.

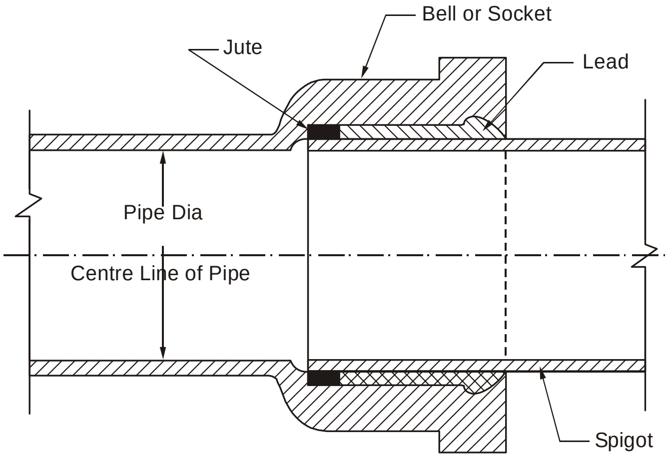


Figure 4.1 : A Socket and Spigot Joint

The joint is somewhat flexible and allows the pipe to be laid on flat curves without the use of special mountings. Mostly mains and sub-mains of cast iron, spun iron or steel are joined with this type of joint.

4.3.2 Flanged Joint

Flanged joints are generally used at locations where it becomes necessary to disjoint the pipe off and on, such as at pumping stations, filter plants etc. Cast iron pipes which are to be joined with flanged joints are cast with heavy flanges at both ends whereas in case of steel pipes, flanges are separately cast and screwed or welded at both ends of the pipe length.

The flanges are put together and a rubber washer known as gasket is kept between flanges and fixed by means of nuts and bolts. The gasket is not less than 1.5 mm thick.

The joints are strong, rigid and easy to repair.

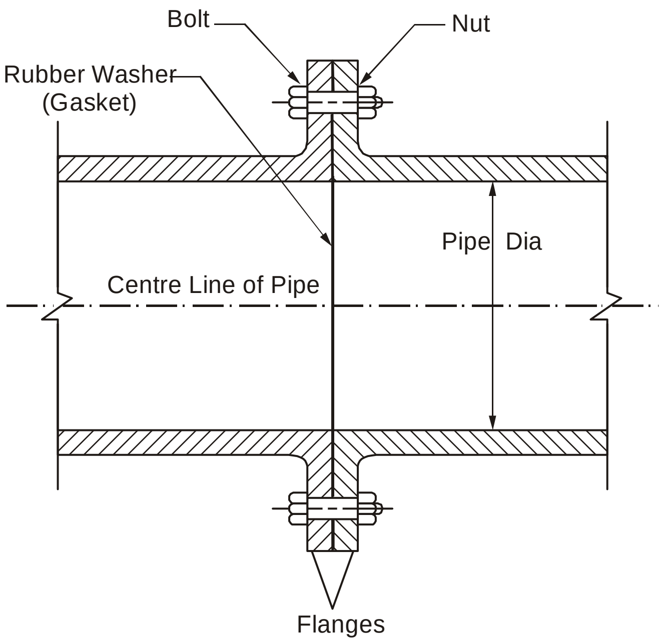


Figure 4.2 : A Flanged Joint

4.3.3 Expansion Joint

Expansion joints are provided in metal pipe lines at suitable intervals to take into account the change in pipe lengths due to temperature variations. The socket end is connected rigidly to an angular ring which slides freely over the spigot end.

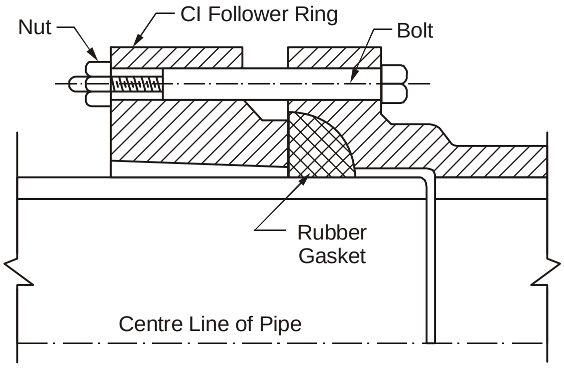


Figure 4.3 : An Expansion Joint

A small gap is kept between the face of the spigot and inner face of the socket. A rubber gasket is provided between the socket and spigot and finally they are tightened with nut and bolt.

4.3.4 Collared Joint

Concrete pipes are mostly joined by collared joints. Pipes are having spigot at one end and socket at the other and jointed by a gasket or hemp and clean cement. It is further strengthened by providing a concrete collar wide enough to cover the overlap of the joint. Pipes of bigger diameters are joined with collared joints. Pipes without sockets are put butting together and joined with collar.

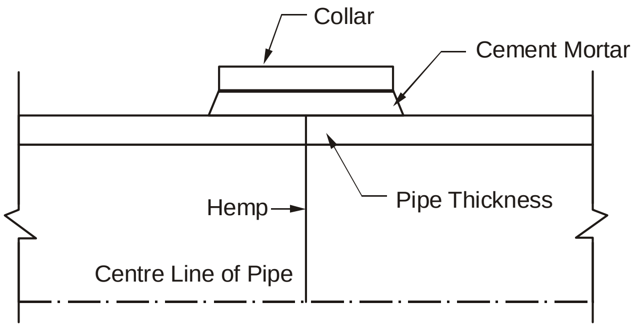


Figure 4.4 : Collared Joint

Since Welding techniques have developed to a great extent, now-a-days practice is developing to join pipes by welding. Specially, metal pipes are most suitable for welding.

4.4 TESTING FOR PIPE LINES

After laying and joining, the pipeline has to be tested for leakage. Following procedure is adopted for testing. The pipe is slowly charged with water so that all air is expelled from the pipe by providing a 25 mm inlet with a stop cock and allowed to stand filled with water for a few days and then tested under pressure. The test pressure is usually 5 kg/cm^2 or maximum working pressure plus 50 per cent, whichever is greater. The pressure is applied by means of a manually operated test pump or in case of long pipes, or pipes of large diameter, by a power-driven test pump. The test pump having been stopped, the test pressure will maintain itself without measurable loss for at least half an hour. The pipe is tested in sections as the work of laying proceeds. It is preferable to keep the joints exposed for inspection during the testing. The open end of the pipe is temporarily closed for testing under moderate pressure by fitting a watertight expanding plug which is available in the market. The end of the pipe and the plug is secured by struts to resist the end thrust of water pressure in the pipes. Air should not be used for testing water mains. The test should be done always with water. (For more details, IS 2065-1972 may be referred.)

SAQ 1

(a) List the various types of pipe which are used for water supply system.

(b) What is the main reason of corrosion of pipes?

(c) With the help of neat sketch explain flanged joint for connecting water pipes.

4.5 WATER DISTRIBUTION

Depending on the topography of the region, water may be fed to distribution system by :

- gravitational system,
- direct pumping, and
- combined system.

The objective of distribution system is to supply water to the consumers with adequate pressure and quantity. The system of distribution largely depends upon topography of the area and constraints such as availability of fund.

4.5.1 Gravitational System

In this system, water from high level source is distributed at lower levels by simple action of gravity without pumping. Since pumping is not done, sufficient difference of elevation must be available between source and distribution points so that adequate head is available at the distribution points after allowing friction and other losses through pipes and valves etc.

4.5.2 Direct Pumping

In the direct pumping system, the treated water, instead of pumping to the service or distribution reservoir, is directly pumped to the distribution mains. Hence, storing of treated water is not needed anywhere in the system. Since supply is done directly to the distribution mains and services, high lift pumps are required to overcome the friction losses at different stages and to have some residual head at distribution points so that water may rise at higher storeys of buildings. Since water demand vary, the high lift pumps are required to be run at variable speed to meet water requirement at different time periods. Due to variable speed, the pumps do not work at their maximum efficiency. Hence, the system is not so economical. At the same time, continuous monitoring of pumps is required. Repair and maintenance cost also goes high. The advantage of the system is that the additional cost of constructing distribution reservoir is saved. In case of power failure, either additional cost of generators is to be borne with or there is interruption in supply. Another advantage in this system is that at the time of fire break-out, large quantity of water at higher rate may be obtained. The system is suitable for small areas.

4.5.3 Combined System

In this system of water supply, pumping and gravity system is combined. The system is quite adaptable and can be used in all circumstances. In this system, the treated water is pumped and stored in an elevated distribution reservoir or tank and from the distribution tank, it is fed to the distribution system by the action of gravity.

Pump works at constant and convenient schedule and the pressure can be maintained uniformly during the supply. At the time of higher demand, additional demand is supplemented by distribution reservoirs. Even at the time of power failure, the supply can be maintained without any interruption. Due to detention of treated water in the distribution reservoir, quality of water improves. The excess water during low demand period is stored in the distribution reservoir.

If the source of supply is at low elevation, then by small lift pumps, the water is taken to the treatment units. Otherwise, if the source is at higher elevation, then water flows to the treatment plant by gravity. The combined method can be suitable in all types of topography and circumstances, hence, it is universally accepted and used.

4.6 SYSTEMS OF SUPPLY

Water is supplied to consumers in following two ways :

(a) Continuous supply.

(b) Intermittent supply.

In **continuous supply system** water is made available to consumers twenty four hours a day whereas in **intermittent system** consumer get water supply at pre-determined hours of day. The rate of supply in the continuous system can be kept low and pressure may be also low. In such conditions wastage of water through leakage is less because of water being supplied at lower pressure. Lower supply rate requires comparatively lesser size of distribution pipes, making the system economical. In the intermittent supply, water is supplied mostly at peak hours or if the shortage of water is there then the whole distribution area is divided into different zones and water is supplied to the different zones at different fixed timings. In this system, usually an overhead tank is provided at top of each building and this tank gets filled up when there is supply and thus residents get water continuously in their house even there is intermittent supply from the water works. In our country, this system is followed in most of the water works. Although intermittent system seems to save water, but is discouraged because of following :

- It does not cover fire risk during non-supply hours. Therefore, there might be difficulty in finding sufficient water for fire fighting purpose during the hour of need.
- It is not consumer friendly method of water supply as it keeps them on their toes for collecting water as soon as supply is restored.
- It might induce pollution through leaky joints.

4.7 LAYOUT OF DISTRIBUTION SYSTEM

The distribution pipe system consists of mains, sub-mains, branches, lateral and finally service connections. Pipes except the service connections are usually made of cast iron with some type of coating to avoid rusting, whereas for service connections galvanised cast iron pipes are used. In large cities, the area is divided into several zones and each zone has separate distribution reservoir or tank. In smaller towns, the distribution mains mostly start from the treatment plant and distribute water through different branches and laterals.

Distribution pipes are laid on one side of the road, but in thickly populated areas with wider roads, a subsidiary lateral is provided on the other side of the road and the lateral are cross-connected to the main at suitable intervals. Since distribution pipes are mostly laid along the road, below the footpath, their layout generally follow the layouts of the road. Depending upon local conditions and orientation of roads, any of the following pattern of layouts is adopted singly or in combination.

(a) Dead end or tree system.

(b) Grid system or reticular system.

(c) Ring or circular system.

(d) Radial system.

4.7.1 Dead End or Tree System

The system is also known as tree system because as a tree has a trunk and branches and sub-branches at different heights, the system has one main pipe from which a number of sub-mains bifurcate and from each sub-mains several branched pipes separate out which are known as laterals. From lateral house connections are given to different houses and other units as shown in Figure 4.5.

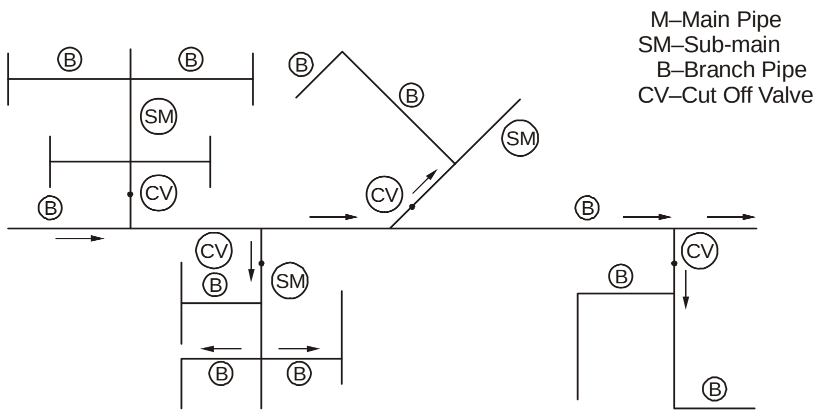


Figure 4.5 : Dead End System

Such type of distribution system is followed for old towns where the houses come up in a very unplanned way and in such cases one water main follows the main road and several water pipes are extended as per requirement. Although the system is easy to design and is cheap and simple and can be extended as per requirement, it has got some drawbacks also. Water can reach at a particular point only through one route hence, if some fault creep in, water supply gets disturbed in that area because water conveyance is uni-directional only. There are many dead ends which prevent free circulation of water. At the same time stagnant water has to be removed periodically by providing scour valves at dead ends, and this results in wastage of treated water.

4.7.2 Grid System or Reticular System

In this system one main pipe runs through centre and branches and laterals run in grid pattern which are inter-connected as shown in Figure 4.6.

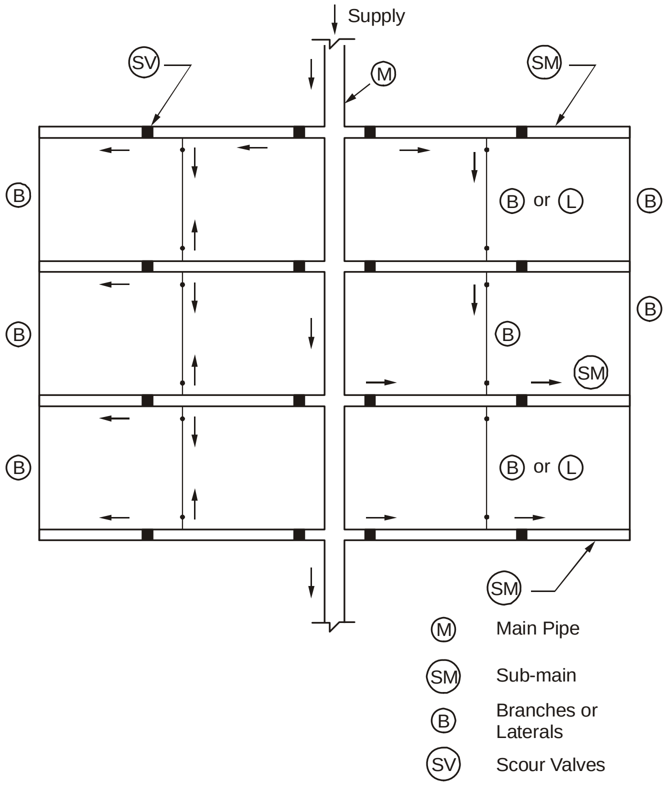


Figure 4.6 : Grid System

Since the mains, branches and laterals are inter-connected hence dead ends are eliminated and water is in continuous circulation reaching at different locations through more than one route. Subsequently, pipe friction is minimised and size of pipe gets reduced and at the time of repair in any section, an alternative route is available for supply. At the time of fire, water can be diverted to the affected area by closing cut off valves of other areas. To regulate the supply, valves are provided at different locations as shown in the figure. Since the pipe lines get water from different directions, design is a bit difficult, size of pies are larger and more number of sluice valves are required.

The system is most suited for a planned city where road and streets are provided in planned rectangular and square grid patterns. The system is also known as interlaced system.

4.7.3 Ring or Circular System

The system consists of a main pipe all round the area. The area to be served in rectangular, square or a circular pattern. Figure shows a typical ring system in a rectangular form.

Sub-main and branches run mostly perpendicular to main and water on all sides of the area goes to service through pipes connected to the nearest main. Hence, sufficient supply head is available. The system is similar to grid system but has got more advantage of having more service head due to main running all around the area. This system is also suitable for a planned city or township.

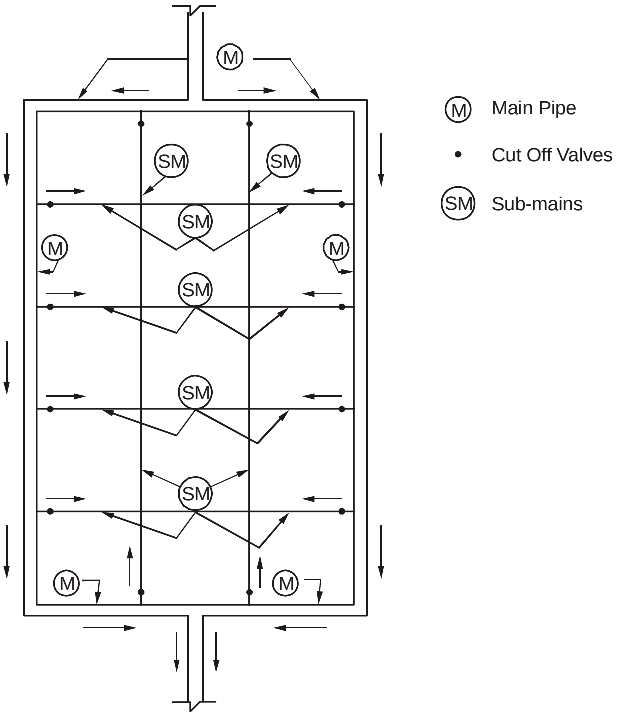


Figure 4.7 : Ring System

4.7.4 Radial System

In this system, a very big area is divided in several zone and at the centre of each zone a distribution reservoir is kept which is fed by sub-main which takes water from main running across the area. From each distribution reservoir, branches or laterals radiate in all direction as shown in Figure 4.8. Radiating pipes are connected to peripherals. Hence, the system works as a grid system without any dead end. Divding the area into zones ensures the equalisation of supply throughout the area. The zoning depends upon population density, type of locality and topography of the area. The method gives higher service head and efficient water distribution. The system of radial distribution is shown in Figure 4.8.

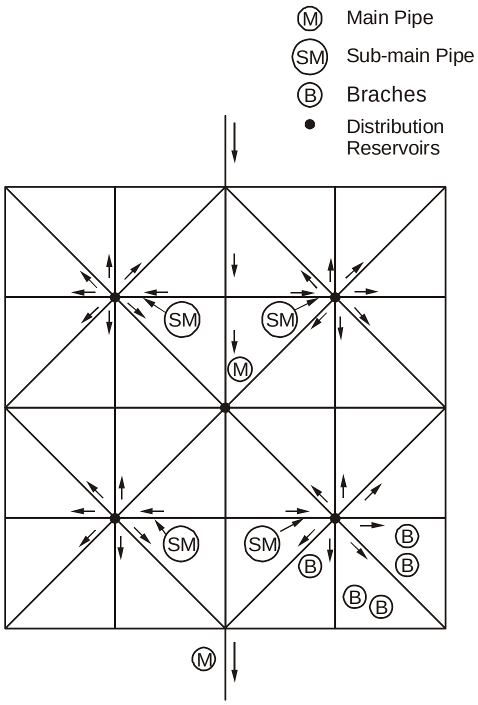


Figure 4.8 : Radial System

4.8 APPURTENANCES FOR HOUSE WATER CONNECTION

Appurtenances used in house water connection include ferrules, goose neck pipe, service pipe, water meters, stop cock, water taps, bib cocks, spouts, pipe fittings such as bends, crosses, tees, elbow, unions, caps, plugs, flanges etc.

Ferrules

It is a right angled sleeve made of non-ferrous metal mostly of brass or gun metal. It is joined to the opening drilled in the water main with the plug. A tee branch connection off the main is used to connect the service pipe leading to domestic connection. Cross-section of a common ferrule is shown in Figure 4.9.

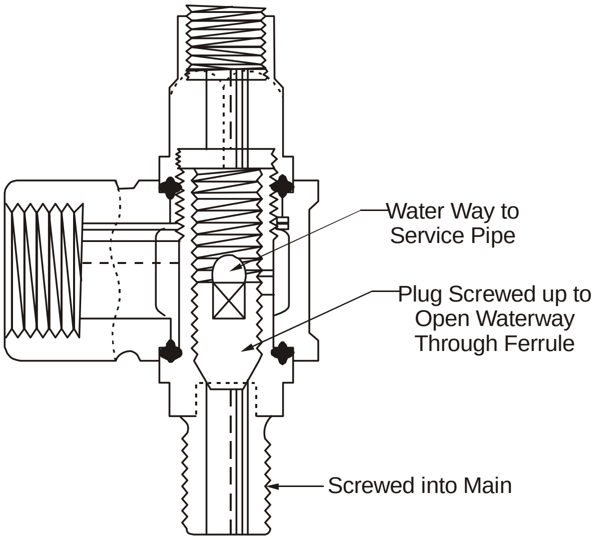


Figure 4.9 : A Typical Ferrule for Under-Pressure Tapping in a Service Main

The ferrule is having bore not more than 25 mm. Ferrule of 20 mm bore and above is used in mains having internal diameter more than 100 mm.

Goose Neck

It is a small curved flexible pipe for making connection between ferrule and service pipe. They are usually of about 75 cm length and made of lead to provide flexibility. This flexible pipe is provided to take care in the settlement of the service pipe due to overburden load in due course. It provides ease in connecting service pipe with the ferrule.

Service Pipe

It is a galvanised iron pipe of nominal size (internal diameter) less than 50 mm. It is laid below ground level making a trench. Care has to be taken that no sewer or drainage pipe is laid in the trench in which service pipe is laid. It supplies water to individual buildings through the municipal main and as discussed earlier is connected to the main through ferrule and goose neck.

Stop Cock

It is normally provided before the water meter. It is connected at the end of the service pipe and close to the boundary wall of the premises in an accessible position. It is housed in a small masonry chamber with a removable cover for stooping or opening the water supply to the premises.

When water meter is provided, both the water meter and stop-cock is housed in the same chamber.

It is provided at the entrance of the water connection to the premises and when closed, stops water supply to the premises thus helping in some major repair and maintenance work. The cross-section of a typical stop-cock is shown in Figure 4.10. Water passes through the opening when the stem of the valve is raised. When the stem is brought down, it rests against the seat and passage of water is closed thus supply of water is stopped.

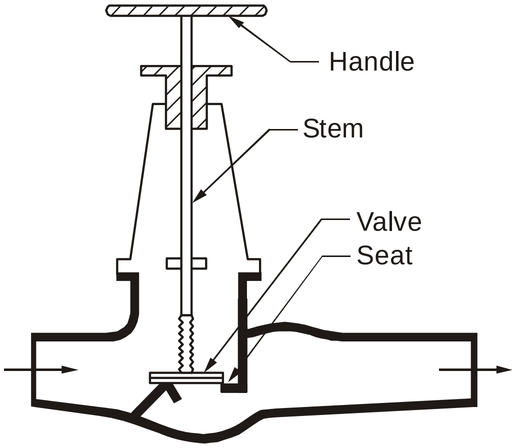


Figure 4.10 : A Typical Stop Cock

Bib Cocks

In common language, it is also called water taps. They are valves provided in the plumbing system to take out water in the consumers premises such as both room, kitchen etc. Several varieties of water taps are available in the market. Two typical types of bib cocks in common use in houses are shown in Figure 4.11. By turning the handle of the bib cocks, the orifice opening can be increased or decreased through which water flows. They are known as compression type bib cocks. In one type, the compression bib cock, by turning the stem down, the washer sits on the orifice seat which has no renewable washer. In another type, the seat has got renewable seat washer also.

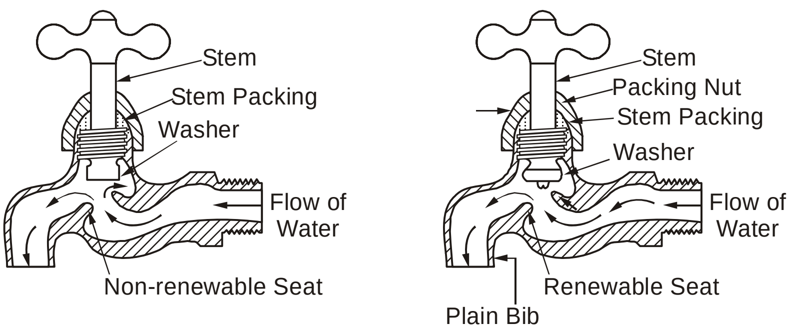


Figure 4.11 : Bib Cocks

In the push type of big cock, it opens with a slight push given vertically upward and closes down automatically due to self-weight. Such valves are mostly used in public places to avoid wastage of water from compression type (handle type) of bib cock which may be left opened by irresponsible persons. Cross-section of push type bib cock is shown in Figure 4.12.

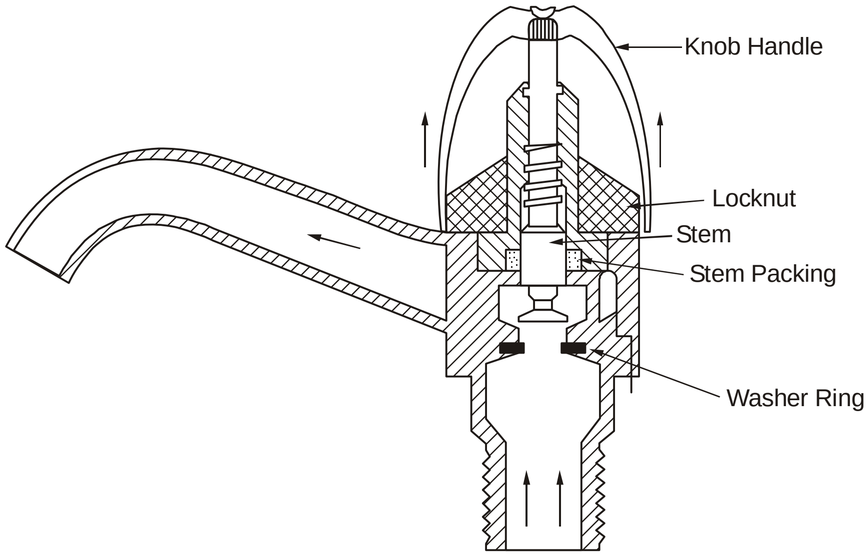


Figure 4.12 : Push Type Bib Cock

Water Meter

Water meters are connected after the stop cock to measure the quantity of water supplied to a premises. With the help of reading in water meter, quantity of water consumed is accessed and consumer are charged accordingly. They are classified according to the method of measuring flow. Mainly there are two types of meters. These are

- velocity or inferential meters, and
- positive or displacement meters.

Velocity or Inferential Meters

Such types of meter work on principle of measuring the horizontal velocity of water flowing through them. Higher the velocity of water more water will discharge through the meter and, thus, higher the consumption. Turbine meter and venturimeter are examples of this category.

Positive or Displacement Meters

They work by the flow of water causing a piston to reciprocate within a cylinder and communicating the movement finally to a system of dials, which register the quantity of flow. But such type of meters are very bulky and heavy. Hence an improvement has been done and the improved ones are known as semi-positive meters. They are widely used for domestic supplies. Positive or displacement meter may be rotary, oscillatory or rotating disc type.

Pipe Fittings

For water supply plumbing, various types of fittings are required. They are bends, crosses, tees, elbows, unions, caps, plugs, flanges, nipples, etc.

Bends, crosses, tees and elbows are used to change the direction of pipeline. Tees are provided to take out flow in normal direction to the main flow. Elbows are provided to turn the gradual direction of the pipe line by 90^o. Crosses are provided to divert the flow in four directions whereas bends are provided to turn the direction of the pipe line at a desired angle.

Caps and plugs are used to close the end of a pipe line. Nipples are used to reduce the section of a pipe and unions are used to change a section of pipe when required.

Figure 4.13 shows a typical connection of a water supply plumbing showing different types of pipe fittings and other appurtenances.

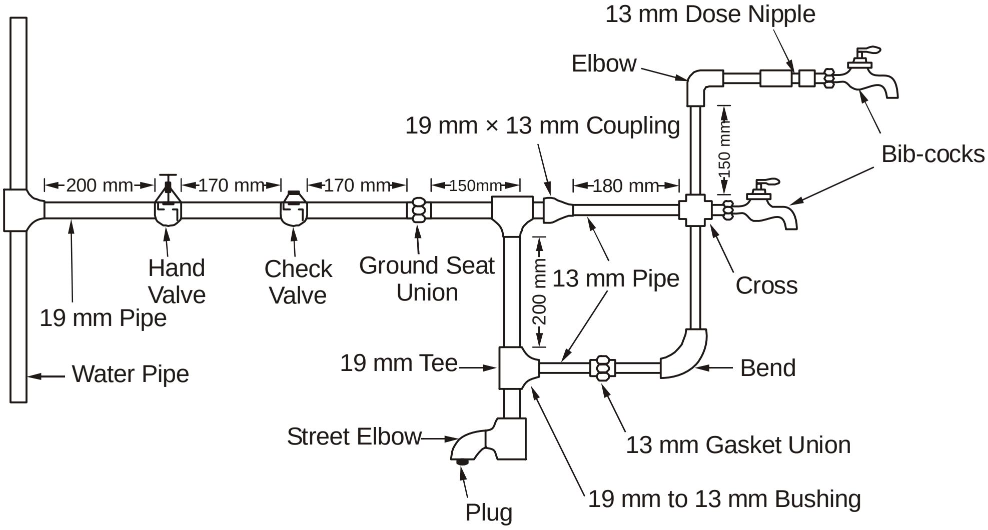


Figure 4.13 : A Piping Assembly Containing the Common Pipe Sizes and the Most Common Fittings

SAQ 2

(a) With the help sketches, illustrate various types of layout used in water distribution system.

(b) Explain the general methods of distribution of water commonly used in water supply system.

(c) List various appurtenances used in house water connection.

4.9 PUMPING OF WATER

As we have seen in the previous sections that if water cannot be obtained at an elevation sufficient to admit a satisfactory gravity pressure at the point where it is to be used, pumping machinery becomes necessary. Pumps are mechanical device or arrangement by which water is forced to flow at increased pressure. The process of using pump is called pumping.

4.9.1 Conditions of Pumping

The conditions in which a pump is to be put and the places where it is to be installed are grouped into following classes of service :

(a) Deep well

(b) Low lift

(c) High lift

(d) Boosting

(e) Fire-fighting

(f) General service for small supplies

(g) Standby

In case of ground water sources, the water is lifted from wells or tube-wells and collected into a collecting basin from where the water enters the treatment plant. After the treatment, water is again lifted so as to force into the distribution system. Sometimes, **deep well** pumps may be arranged to discharge water directly into the distribution system. **Low-lift** service involves pumping of water from the source, lake or stream into a low-level reservoir or purification plant.

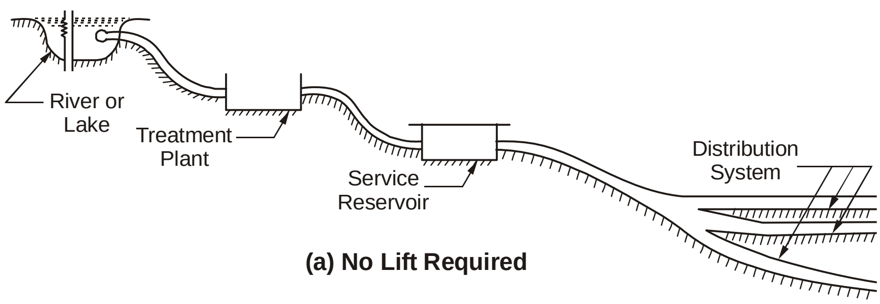
High lift service involves the pumping of water from purification plant or low service reservoir or from source itself into the distributing system. This part of pumping system is most expensive both in initial cost and cost of operation and demands the most careful consideration of economy and dependability.

Booster pumps are used to increase the pressure in certain parts of the system due to high elevation or inadequate pressure arising from excessive loss in long distributing pipes. Booster pumps are also used to provide water in the upper storeys of tall buildings.

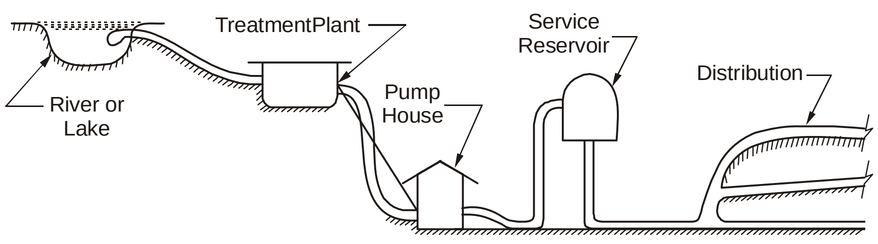
In modern fire protection measures, the municipal water supply is brought to the hydrant nearest to the fire. The special fire pumps which boost the pressure to that required for efficient **fire-fighting** are located in the tall buildings, factories or in vehicles.

In many cities located adjacent to a surface supply, special high pressure mains have been built serving highly congested areas.

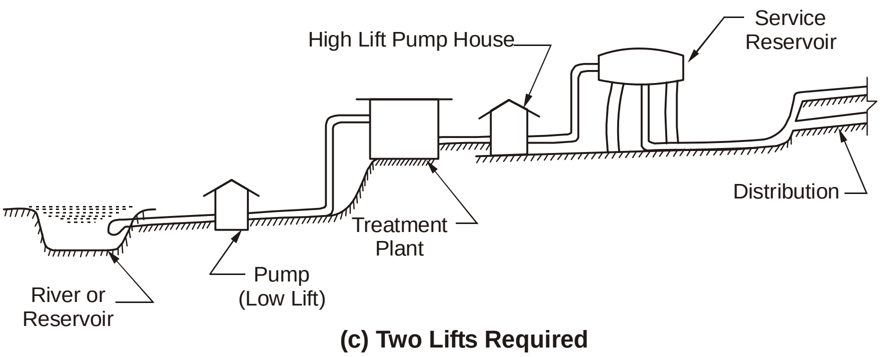
Small water supplies of low heads are provided for parks, farms and small estates. Some special types of pump are available to meet such type of demand. **Stand-by pump's** use when other ordinary pumps fail are extremely important in certain industrial plants and hospitals as well as in municipal pumping stations for fire protection. Prime specifications for this service are dependability of power supply, prime movers, pump pipes and controls. Economy in such case is secondary consideration. Four different cases of pump requirements have been shown in Figure 4.14.



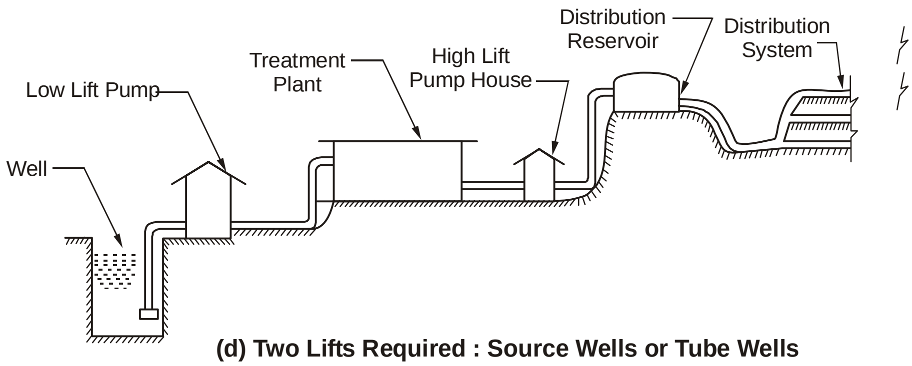
(a) No Lift Required



(b) Only One Lift Required



(c) Two Lifts Required



(d) Two Lifts Required : Source Wells or Tube Wells

Figure 4.14 : Conditions for Pumping

4.9.2 Type of Pumps

Pumps may be classified as :

- positive displacement pumps (rotary and reciprocating type),
- rotodynamic pump (centrifugal and deep-well turbine pumps), and
- miscellaneous type of pumps.

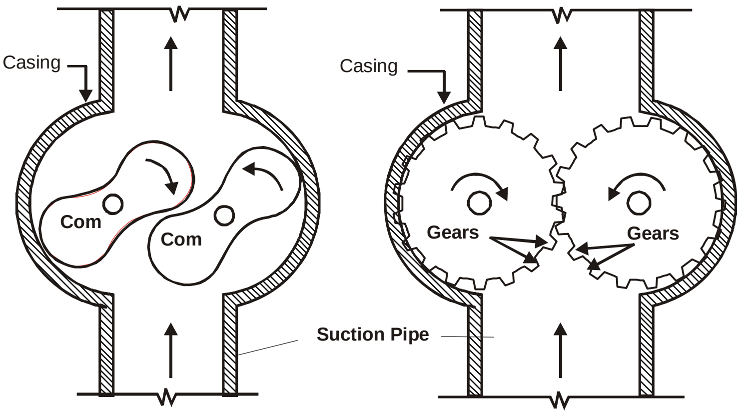
Positive Displacement Pump

In positive displacement pump, liquid is sucked in and then actually pushed or displaced due to the thrust exerted on it by a moving member, resulting in the lifting of the liquid to a higher elevation. The displacement of liquid can be brought about either by

- rotary movement, and
- reciprocating movement of the displacing mechanism.

Rotary movement is obtained in rotary pumps by using two cams or gears as shown in Figure 4.15. In this type of pump, two meshed gear rotate in opposite directions in the casing, the flow of water being around the outside of the gears with backflow prevented where the gears are meshed together giving direct displacement with smooth and non-pulsating flow. However, some internal contact of rotating parts is inevitable which cause a minor turbulences. Rotary pumps are usually used for liquids, such as, oils with good lubricating properties which causes a minor turbulence.

Reciprocating Pump, in its simple form, has a cylinder into which a piston moves to alternately suck and push water (Figure 4.16). Flow rate of water in such pumps almost wholly depends on the speed of the pump. Forward and backward motion of the piston is brought about by a prime mover like an electric motor, an oil engine or a steam engine. Obviously the usual



(a) With CAMS **(b) With Gears**

Figure 4.15 : Typical Rotary Pumps

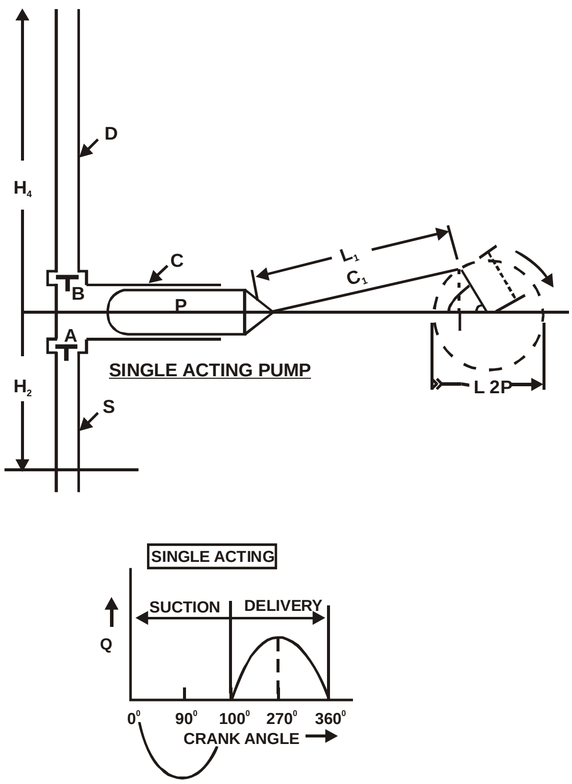


Figure 4.16 : Single Acting Reciprocating Pump

rotary motion of the electric motor is to be first converted into a reciprocating motion by a suitable mechanical device. Usually the speed of the electric motor is suitably brought down to the working speed of the reciprocating motion of the piston. The cylinder is connected to the suction and delivery pipes. At the start of both suction and delivery pipes, a non-return valve is fitted which permits the flow only from suction pipe into the cylinder, and from the cylinder into the delivery pipe. One can easily imagine that the flow rate would be pulsating (Figure 4.16) and, thus, would not be uniform unless special appurtenants are provided to even out the pulsations. Pressure rises that can be achieved, is theoretically very large and limited only by the mechanical strength of the cylinder and the pipe system. Reciprocating pump are commonly used to achieve large rise in delivery pressure heads, but the flow rates are restricted by the speeds of the piston and the discharge is relatively small and uneven.

Rotodynamic Pump

A roto-dynamic pump has a wheel or a rotating element which rotates the water in casing thus increasing the energy level due to a combination of centrifugal energy, pressure energy and kinetic energy.

A centrifugal pump is the most common among the rotodynamic pumps. Unlike a positive displacement pump, in which the liquid is simply pushed out of the pump, a centrifugal pump changes the hydraulic energy such that the liquid is lifted to a higher level. The basic principle on which a centrifugal pump works is that when a certain mass of liquid is made to rotate by an external force, it is thrown outwards from the axis of rotation and a centrifugal head is impressed on it. This enables the liquid to rise to a higher level. If more liquid is made available at the centre of rotation, a continuous supply of the liquid to the higher level may be ensured. The mechanism by which a liquid is made to rotate consists of a revolving wheel with vanes, which is called an impeller. During the passage of the liquid through the impeller, angular momentum changes, and this circumstance also results in the increase of the pressure head of the liquid.

The main parts of centrifugal pump that is impeller, casing, vortex chamber, guide vanes, suction pipe and delivery pipe are shown in Figure 4.17.

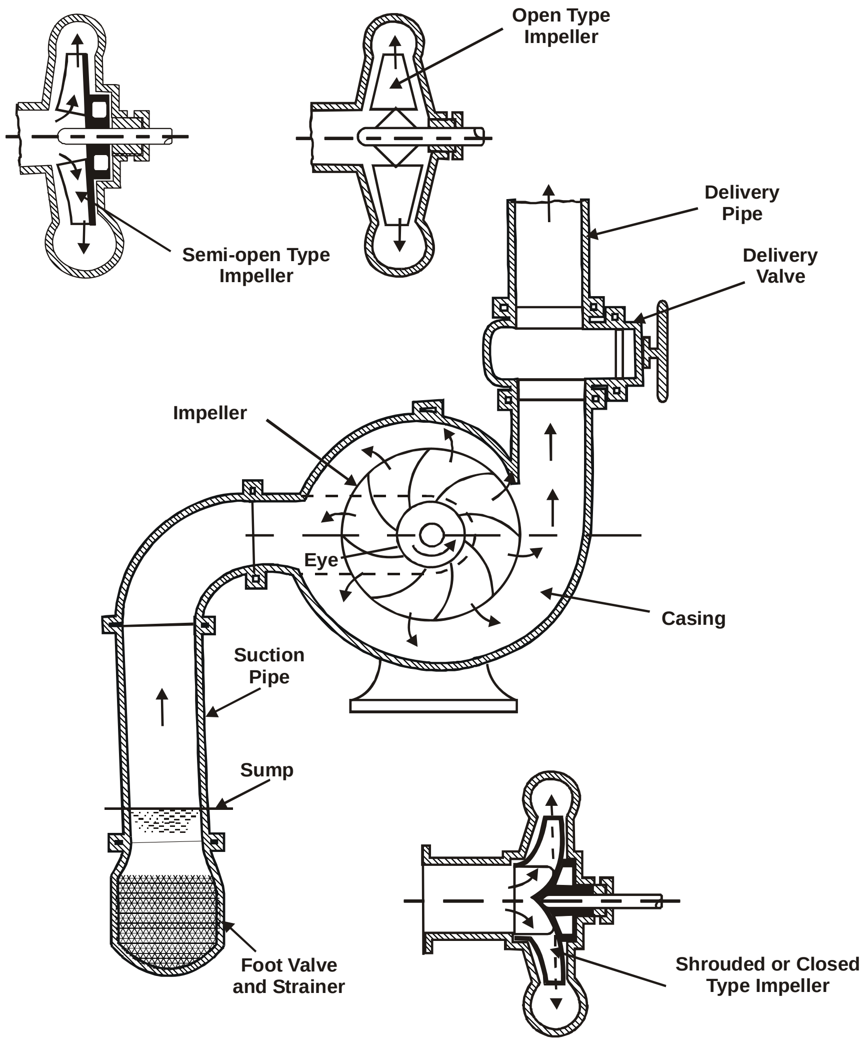


Figure 4.17 : Component Parts of Centrifugal Pump

The main advantages of a centrifugal pump over a reciprocating pump is the former's larger discharging capacity. A centrifugal pump can also be used to pump turbid (muddy) waters which may damage the valves of a reciprocating pump. A centrifugal pump is usually connected directly on to an electric motor or an oil engine, while a reciprocating pump needs a speed reduction mechanism, like a pulley and a belt drive.

Table 4.1 compares the important differences in operating characteristics of centrifugal and rotodynamic pumps.

Table 4.1 : Important Differences in Operating Characteristics of Centrifugal and Reciprocating Pumps

Centrifugal	**Reciprocating**
(i) Discharge, *Q*	
Flow rate is completely steady and there is practically no limit to the output	Flow is pulsating and output rarely exceeds 200 m^3/hr.
(ii) Head, *H*	
High heads can be obtained through multi-stages running at high speeds; economical only in case of relatively large outputs.	High heads can be obtained efficiently even at low speeds and comparatively low rates of flow.
(iii) Speed, *n*, of the Pump (or its prime mover)	
The usual range of speed is 1000 rpm to 3000 rpm. Direct coupling to electric motors is possible. Step-up gearing is needed only when the prime mover has low speed. Turbine-driven pump can run even at 6000 rpm.	The usual range of speed is 100 to 300 rmp and this speed is seldom exceeded. A speed reduction gear or pulley is required if the prime mover is an electric motor. Therefore, direct coupling of pump is possible with a slow speed prime mover only.
(iv) Efficiency	
Greatly affected by (*Q/H*) ratio. Efficiency is low for small *Q/H*. Efficiency falls when water with suspended matter is pumped.	Practically independent of (*Q/H*) ratio. Efficiency is independent of liquid property like viscosity.
(v) Method of Control *Various cases regarding operational parameters arise :*	
(a) Speed, *n*, is constant	
Q depends on *H*.	*Q* is independent of *H*.
Reduction of *Q* is easily made by a throttling valve, although usually with a consequent loss of efficiency.	*Q* can be reduced by returning a part of it through a branch in suction involving a loss of efficiency. *Q* can be varied by varying the stroke, without loss of efficiency, but a special design is required.
(b) Head, *H*, is constant	
Q can be changed by varying the speed and by throttling. The latter method involves loss of efficiency.	*Q* can be changed by varying speed without loss of efficiency. A by-pass valve can be used to change *Q*, but this entails loss of efficiency.
(c) Discharge, *Q*, is constant	
Head (*H*) can be changed by altering the speed.	*H* adapts itself automatically to the prevailing back-pressure without loss of efficiency.
(vi) Suction Efficiency	
Priming is normally required.	When started without back-pressure, they are self priming to some extent.
(vii) Starting Torque	

A comparatively low starting torque is required; direct coupling to an electric motor or oil engine is possible.	Starting torque is approximately equal to running torque as large masses are to be accelerated.
(viii) Starting of Pump with Long Pipe Lines	
Special measures are unnecessary since the static water head is accelerated to full velocity at a discharge *Q* in accordance with the gauge pressure at $Q = 0$.	A large cushion chamber is required to store the discharge until the contents of the pipe line have been accelerated to full velocity.
(ix) Stop Valves	
No stop valves should be fitted in the suction line, but non-return and stop valves should be installed immediately after the delivery branch.	If a stop valve is to be fitted in the discharge line, it is essential that a safety valve rated for full discharge is fitted between the pump and the stop valve.
(x) Floor Space Required, Weight, Dimensions	
Owing to high speed, rotary motion, and continuous flow, it is possible to obtain high output with light, compact units.	Reciprocating masses and moving valves set a limit on the number of strokes per minute resulting in large swept volumes for same output; and, thus greater weights and dimensions are encountered.

Miscellaneous Type of Pumps

In addition to above types of pumps, jet pumps, hydraulic pumps and submersible pumps are normally used in water supply system.

Jet Pumps

Jet pumps operate on the ejector principle that a stream of water or compressed air is injected into the throat of a venturi nozzle, which produces low pressure and draws additional fluid from an external source into the throat. The combined stream is expelled in the diverging venturi tube and by the time it has reached the outlet end of the tube it acquires considerable pressure head.

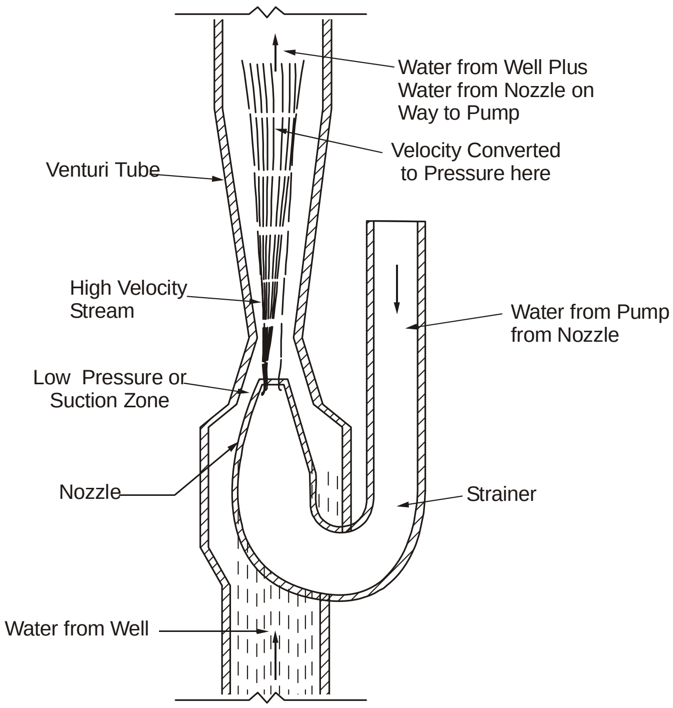


Figure 4.18 : Jet Pump

Small pumps of this type are used to prime centrifugal pumps. They are also manufactured for pumping water from small deep wells. A foot valve is installed in the intake to keep pump primed when not in operation. They are designed to lift water around 60 to 70 meters. The efficiency of such a pump is low. But they are compact and light, making it portable and easy to handle.

Hydraulic Ram

A hydraulic ram is a kind of a pumping arrangement which does not utilize any outside power. It is a pump of impulse type which raises water by the periodic application of force suddenly applied and suddenly discontinued. Figure 4.19 shows the set up of a hydraulic ram.

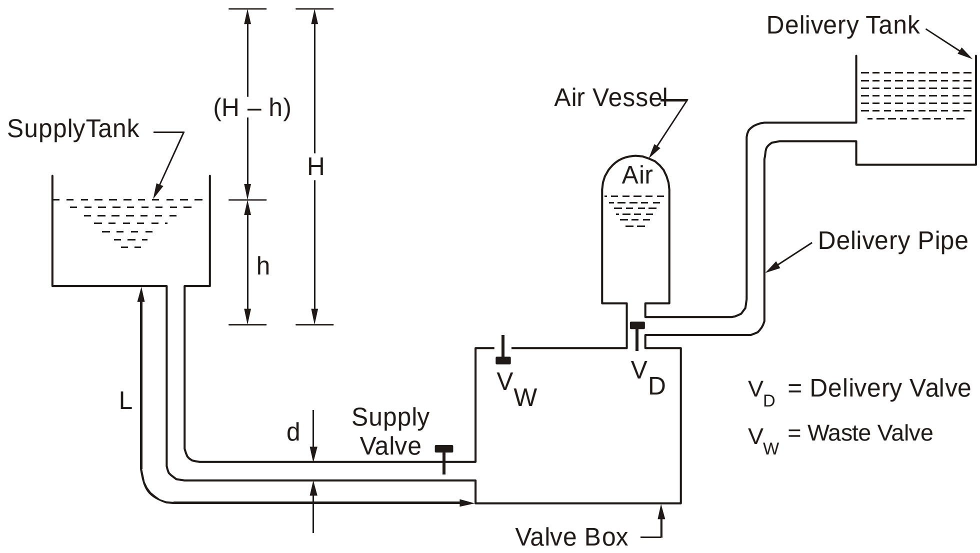


Figure 4.19 : Line Diagram of a Hydraulic Ram

It consists of a valve box in which low head water flows. The box contains a waste valve, V_W, and a delivery valve, V_D, which are non-return valves that allow the flow only in one direction. Valve V_D is connected with an air vessel which is connected to the delivery tank as shown in Figure 4.19. It works on the principle of water hammer. When a flowing liquid is suddenly brought to rest, the change in momentum of liquid mass causes a sudden rise in pressure. This rise in pressure is utilized to raise a portion of the liquid to higher level.

Submersible Pumps

Submersible pumps are centrifugal pumps installed under water. Actually they should be termed as "submersed motor" pumps because the pump is directly connected to an electric motor sited immediately below it and the motor is capable of running under water. As per modern practice, the windings are surrounded by water from the well or bore-hole so that water can act as a coolant and also as a bearing lubricant. In some models whole motor is sealed off from water. The motor is a squirrel cage. AC motor running at a fixed speed unless a variable speed frequency change is interposed on the line to change the speed. Power to the motor is fed by waterproof cables clipped to the side of the rising main. They can be easily and quickly installed and can be of small diameter.

4.9.3 Horse-power of Pumps

The horse-power required for the pumps (HP) is given by :

$$\text{HP} = \frac{WH}{75}$$

where, W = Weight of water in kg per second, and

H = Total head in meter.

This is known as Water Horse-power (WHP).

Brake horse-power (BHP) is calculated by dividing Water Horse Power with efficiency of pump (E).

$$\text{BHP} = \frac{WH}{75\,\text{E}}$$

In the above equations, total head (H) is normally obtained by following equation:

$$H = h + h_f$$

where, h = total static head or difference in level between the lowest water level in the well and full supply level of the tank whereas h_f = Head lost due to friction.

$$h_f = \frac{flv^2}{2gd} \quad \text{(modified Darcy-Weibach formula)} \qquad \ldots (4.1)$$

f = Coefficient of friction,

l = Length of pipe in meter,

v = Velocity of flow in meter per second,

g = Acceleration due to gravity = 9.81 m/sec^2,

d = diameter of pie in meter, and

Q = Discharge in m^3 per second.

$$Q = \frac{\pi d^2}{4} \,.\, v \qquad \ldots (4.2)$$

Now h_f can be calculated as

$$h_f = \frac{f\,l}{2 \times 9.81 \times d} \times \left[\frac{4Q}{\pi d^2}\right]^2$$

4.9.4 Selection of Pumps

The choice of type of pump to be used depends on the following factors :

(a) Reliability of service.

(b) Initial cost.

(c) Maintenance cost, including depreciation.

(d) Cost of energy and labour.

(e) Capacity of pumps.

(f) Efficiency of Pumps.

(g) Suction and delivery heads.

(h) Quantity of water to be pumped.

(i) Type of service – intermittent or continuous.

(j) Type of water to be pumped.

(k) Variation in the rate of pumping heads.

SAQ 3

(a) Draw a neat sketch of centrifugal pump showing its main component.

(b) Differentiate between centrifugal and reciprocating pump with reference to following :

(i) Discharge of flow.

(ii) Efficiency.

(iii) Required floor space.

(c) Design a pumping station to raise water from source to service reservoir with following data :

Water to be raised per day	=	16,000 m^3
Length of suction pipe	=	50 m
Length of rising main	=	150 m
Coefficient of friction	=	0.04
Diameter of pipe (suction and rising)	=	50 cm
Shifts of working of pumps	=	2
Duration of each shift	=	8 h
Combined efficiency of motor and pump	=	75%
Static head through which water is to be raised	=	20 m.

4.10 SUMMARY

In this unit, we have discussed various types of pipes and joints used for transportation of water from the source to consumer and their suitability. Corrosion in pipes causes reduction in their carrying capacity. The factors causing corrosion in water carrying pipes has been explained in this unit.

The layout pattern of water distribution pipe system is selected on the basis of local conditions and orientation of roads. The various patterns of layouts of water distribution pipes commonly used in Indian conditions have also been described.

Water pumping system is important component of water distribution system. This unit also deals with different types of pump commonly used in water supply system.

4.11 ANSWERS TO SAQs

SAQ 1

(a) Various types of pipe are shown in the table given below :

Sl. No.	Types of Pipe	Example
1.	Metal Pipes	(a) Cast iron pipe (b) Steel pipe (c) Wrought iron pipe (d) Copper pipe
2.	Cement Concrete Pipes	(a) Plain cement concrete pipe (b) Reinforced cement concrete pipe (c) Pre-stressed concrete pipe (d) Glass fibre reinforced concrete pipe
3.	Plastic Pipes	(a) Unplasticised polyvinyl chloride (UPVC) pipe (b) Polyethylene pipe (c) Glass reinforced plastic (GRP) pipe

(b) Please refer Section 4.2.1.

(c) Please refer Section 4.3.2.

SAQ 2

(a) Please refer Section 4.7.

(b) Please refer Section 4.6.

(c) Ferrules, goose neck pipe, service pipe, water meters, stop cock, water taps, bib cocks, spouts, pipe fittings such as bends, crosses, tees, elbow, unions, caps, plugs, flanges etc. are commonly used appurtenances for house water connection.

SAQ 3

(a) Please refer Figure 4.17.

(b) Please refer Table 4.1.

(c) Water requirement per day = 16,000 m^3

Total pumping hours = 2 × 8 = 16.

Required pumping capacity per hour = $\frac{1600}{16} = 1000 \text{ m}^3$

Water discharged per second = $\frac{1000}{60 \times 60}$ = 0.278 m^3 per second.

$$W = 1000 \times 0.278 = 278 \text{ kg per second}$$

$$= \frac{fl}{2 \times 9.81 \times d} \times \left[\frac{4Q}{\pi d^2}\right]^2$$

$$= \frac{0.04 \times (50 + 150) \times (0.347)^2}{12.1 \times (0.50)^5}$$

$$= 1.63 \text{ m.}$$

$$H = h + h_f$$

$$= 20 + 1.63 = 21.63 \text{ m}$$

$$E = 0.75$$

Therefore, $\text{BHP} = \dfrac{\text{WH}}{75\text{E}} = \dfrac{278 \times 21.63}{75 \times 0.75} = 106.90$

Hence, we can provide four units of pumps of 30 BHP, making total BHP as 120.

Two additional unit of such pumps may be provided as standby.