CHAPTER 05

Distribution System

INTRODUCTION

After proper treatment, the water is made safe and potable and is to be supplied throughout the district (area) to be served. The function of carrying water from the treatment plant to the individual units such as individual house; industrial units, public places and institutions is completed successfully through a well-planned network of distribution system. Hence, distribution system consists of pumps, mains, distribution or service reservoirs, sub-mains, branches, laterals, valves, meters, hydrants and services.

Pumps are used for lifting and forcing water into the distribution pipes. Mains, sub mains, branches, laterals and pipes of different sections and sizes which carry water as per requirements. Valves control flow of water through pipes. distribution or service reservoirs collect and distributes water as per requirements, hydrants provide large quantity of water at the time of fire in the locality.

5.1 Methods of Distribution

Water is forced in the distribution system in the following ways

(i) Gravitational system (ii) Direct pumping (iii) Combined system

5.1.1 Gravitational System

- The method of water distribution is cheapest by gravitational system.
- In this method, water from high level source is distributed at lower levels by simple action of gravity without pumping.
- This system works well where lakes are available at top of a hill.

5.1.2 Direct Pumping

- In this, the treated water instead of pumping to the service or distribution reservoir, is directly pumped to the distribution mains
- 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 storey of building
- Since, water demand vary, 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

5.1.3 Combined System

- In this system of water supply pumping and gravity system is combined
- 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.

5.2 Systems of Supply

There are two system of supply of water

(i) Continuous supply (ii) Intermittent supply

5.2.1 Continuous Supply

- In continuous supply, water is supplied continuously to the consumers.
- The rate of supply in the continuous system can be kept low and pressure may also be low.
- Lower supply rate requires comparatively lesser size of distribution pipe, making the system economical.

5.2.2 Intermittent supply

- In this system, water is supplied mostly at peak hours.
- In this system, pump of very high capacity may not be required and with the help of distribution reservoir, the system may be more effective.

5.3 Layouts of Distribution System

- The distribution pipe system may consist of main, sub mains, branches, laterals 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.
- The distribution pipe are mostly laid along the road below the footpath. Depending upon local conditions and orientation of roads, any of the following pattern of layouts is adopted singly or in combinations.

(i) Dead end or tree system (ii) Grid system or reticular system

(iii) Ring or circular system (iv) Radial System

5.3.1 Dead End System

- This system is also known as tree system.
- In this system, one main pipe from which a number of submains bifurcate and from each submains several branched pipes separate out which are known as laterals. (Fig. 5.1)
- From laterals, house connections are given to different houses.
- Such type of distribution system is followed for old towns where the houses come up in a very unplanned way.

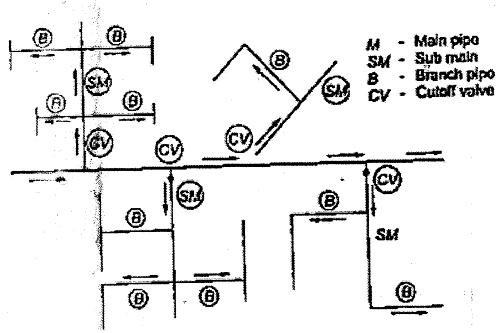


Fig. 5.1 Dead End System

- This system is easy to design and it is cheap and simple
- It has got draw backs that water can reach at a particular point only through one route, hence, if some fault creep in, water supply get disturbed in that area because water conveyance is unidirectional only.
- There are many dead ends which prevent free circulation of water.
- In this system, stagnant water has to be removed periodically by providing scour valves at dead ends and this results in wastage of treated water.

5.3.2 Grid System

- This system is also called as reticular system
- In this system, one main pipe runs through centre and branches and laterals run in grid pattern which are interconnected as shown in figure 5.2.
- Since the mains, branches and laterals are interconnected hence dead ends are eliminated and water reaches at different locations through more than one route.
- At the time of fire, water can be diverted to the affected area by closing cutoff valves or sluice valves of other areas.
- Since, the pipe lines get water from different directions, design is a bit difficult, size of pipes are larger and more number of sluice valves are required.
- This system is mostly suited for a well planned city where roads and streets are provided in planned rectangulars and square grid patterns.
- The system is also known as interlaced system.
- This system has disadvantage that it requires more length of pipe lines and large number of sluice valve (i.e. cutoff valves).
- The design is difficult and costlier.

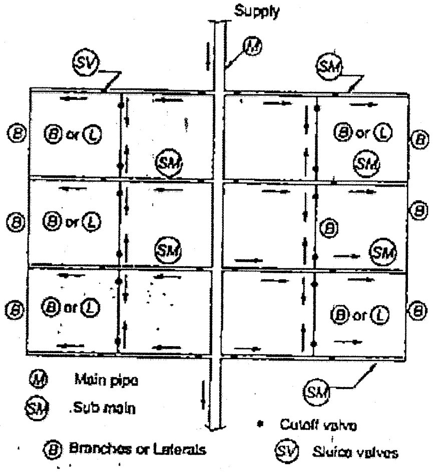


Fig. 5.2 Grid System

5.3.3 Ring System

- This system is also called as circular system
- The system consists of a main pipe all around the area (Fig. 5.3)

5.3.4 Radial System

- In radial system, a very big area is divided in several zone and at the centre of each zone a distribution reservoir is kept.

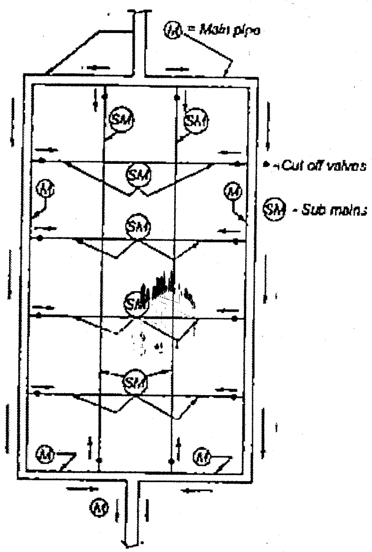


Fig. 5.3 Ring System

- This method gives higher service head and efficient water distribution. (Fig. 5.4)

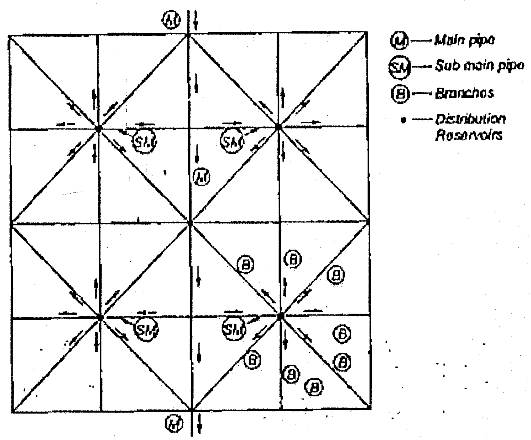


Fig. 5.4 Radial System

Example 5.1 Match List-I (Distribution system) with List-II (Characteristics) and select the correct answer using the codes given below the lists:

List-I

A. Tree system
B. Gridiron or reticulation system
C. Circular system
D. Radial system

List-II

1. Main lines are laid along the periphery covering the entire area.
2. Calculations are simple and accurate flow determination is also possible at any line.
3. Large number of cutoff valve and longer pipe lengths are required.
4. Flow from centre to periphery

Codes:

	A	B	C	D		A	B	C	D
(a)	2	3	1	4	(b)	2	3	4	1
(c)	3	2	1	4	(d)	3	2	4	1

Ans. (a)

5.4 Guidelines For Design of a Distribution System

The mains of distribution system can be divided into three parts having function as below.

(i) The trunk mains (ii) The principal feeder mains
(iii) The networks of small mains feeding services or consumer's supply pipes.

The trunk mains: They are large diameter pipes taking water from source to distribution reservoirs and from distribution reservoirs to the feeder main.

The principal feeder mains: They vary in diameter according to population and the area to be served. In the urban areas feeder may be of diameter 225 mm.

The network mains: The network main have diameter varying from 100 mm to 300 mm.

5.5 Pressure in the Distribution System

Pressure in the distribution system depends on

(i) Domestic use
(ii) Fire demand
(iii) Economic considerations
(iv) Topography
(v) Future demand

For domestic services, the supply pressure depends upon number of storeys upto which water is to be lifted without additional use of booster pumps. For residential area a pressure of 0.6 to 15 kg/cm^2 is considered to be sufficient. Providing greater pressure in pipe than the required valve makes the system costly. Following minimum residual pressure should be provided at the ferrule points

Single storey buildings : 7 m above ground level
Two storey buildings : 12 m above ground level
Three storey buildings : 17 m above ground level

The distribution system is not designed for residual pressure more than 22 m. Hence, for high rise buildings booster pumps should be provided.

5.6 Detection of Leakage in Distribution System

The following methods may be used for detecting the leakage of water from the under ground water mains.

(i) By direct observations
(ii) By using sounding rod
(ii) By plotting hydraulic gradient line
(iv) By using waste detecting meters.

5.6.1 By Using Sounding Rods

- By using sounding rod method, a sharp pointed metal rod is thrust into the ground along the pipe line and pulled up for inspection.
- Its moist or muddly point will preliminarily indicate the presence of leakage.
- The sound of the escaping water can also be heard by placing the ear on the top of the inserted rod.
- Such sounds produced by leaks can also be magnified by a stethoscope type instrument called an aquaphone or a sonoscope; so as to facilitate better hearing of sounds.

5.6.2 By Plotting the Hydraulic Gradient Line

- In such type of method, the pressure at various points along a suspected pipe line are measured and the hydraulic gradient line is plotted.
- The appearance of any kink or change in the slope of the hydraulic gradient line will indicate the location of a leak in the pipe line.

5.6.3 By Using Waste Detection Meters

- Actually the name given of these meters is "misleading" because these meters do not measure the wasted water, but only measure high flow passing through a water main during the period of low consumption such as during night.
- The Deacon's waste water detection meters are widely used as they are quite sensitive and accurate.

Example 5.2 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Test with sound waves in the audible frequency range
B. Fire flow tests
C. Hydraulic gradient tests
D. Coefficient tests

List-II
1. To determine the ability of a distribution system to transmit water with adequate residual pressure.
2. Location and isolation of leaks.
3. To determine the efficiency and adequacy of a distribution system during days of high demand.
4. To determine the internal condition of pipeline with respect to friction loss.

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	2	3	1	4
(c)	1	1	3	2
(d)	4	3	1	2

Ans. (a)

5.7 Analysis of Network of Pipes

Analysis of pipe network includes determination of quantities of flow and head loss in various pipe lines and resulting residual water head.

The Hazen-Williams formula is mostly used for computation of flow through pipes and following two methods are used for analysis.

(i) Equivalent pipe method
(ii) Hardy cross method

5.7.1 Equivalent Pipe Method

- In equivalent pipe method, different small loops are replaced by an imaginary single equivalent pipes having same discharge capacity and causing same head loss.
- The equivalent pipe method is used in solving large network of pipes.

5.7.2 Hardy Cross Method

In Hardy Cross method of analysis, a distribution of flow in the network is assumed and resulting head losses are balanced. Formula of the pipe flow are used to evaluate losses and successive connections are made in the flow until the network is hydraulically balanced. In pipe network, following two conditions are to be satisfied
(i) The algebraic sum of the pressure drops around a closed loop must be equal to zero. i.e. In each loop loss of head due to flow in clockwise direction must be equal to loss of head due to flow in anticlockwise direction.
(ii) The flow entering a junction must be equal to the flow leaving the same junction.

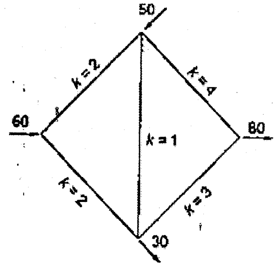
Here, loss of head is $h_L = rQ^n$

Steps

- Assume flow in each pipe satisfying continuity equation.
- Take clockwise flow as positive, anticlockwise flow as negative.
- Modification in discharge $\Delta Q = \frac{(-)\sum rQ^n}{\sum |rnQ^{n-1}|} = \frac{\sum h_L}{n\sum |h_L/Q|}$
- ΔQ is added algebraically

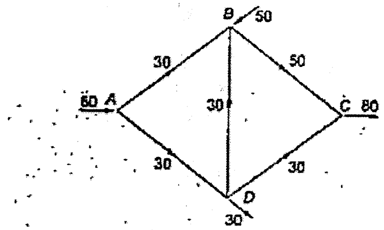
- The direction of h_L is same as discharge
  Clockwise discharge is taken as +ve h_L
  Anticlockwise discharge is taken as – ve h_L

Example 5.3 Evaluate the distribution of flow in the pipe network as shown in figure. As the pipe are rough the flow may be assumed to be turbulent and head loss h_L may be taken kQ^n. The value of k for each pipe is shown in the figure. Take $n = 2$.



Solution:

Assume flow in each pipe and satisfy continuity equation.



Loop *ADBA*:

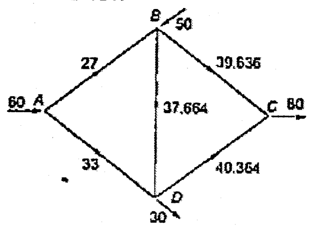
Pipe	Assumed flow Q	k	$h_L = kQ^2$	$[h_L/Q]$	Corrected flow
AB	30	2	1800	60	27
BD	30	1	900	30	27 + 10.364 = 37.364
DA	–30	2	–1800	60	–33
			Σ = 900	Σ = 150	

$$\Delta = -\frac{\sum h_L}{n\sum |h_L / Q|} = -\frac{900}{2\times 150} = -3.0$$

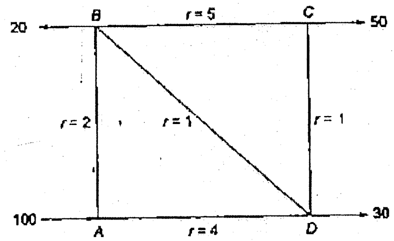
Loop *BCDB*:

Pipe	Assumed flow Q	k	$h_L = kQ^2$	$[h_L/Q]$	Corrected flow
AB	50	4	10000	200	39.636
BD	–30	3	–2700	90	–40.364
DA	–30	1	–279	27	–40.364 + 3 = –37.364
			Σ = 6571	Σ = 317	

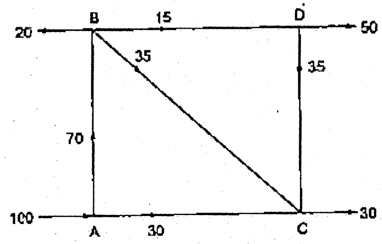
$$\Delta_2 = -\frac{6571}{2\times 317} = -10.364$$



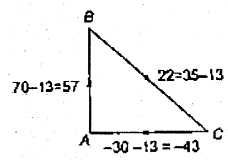
Example 5.4 Find the discharge through each pipe in the network of pipe shown below: (Take $n = 2$)



Solution: Considering Loop ABC



Pipe	rQ^2	$2rQ$
AB	2×70^2	$2\times 2\times 70$
BC	1×35^2	$2\times 1\times 35$
CA	-4×30^2	$2\times 4\times 30$
Σ	7425	590

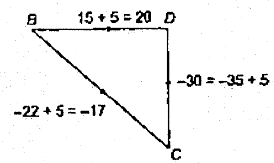


$$\Delta Q = \frac{-7425}{590} = -13$$

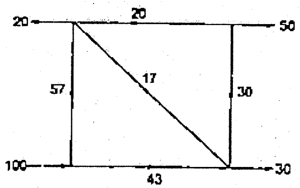
Considering Loop BCD

⇒

BCD	rQ^2	$2rQ$
BD	5×15^2	$2\times 5\times 15$
DC	-1×35^2	$1\times 2\times 35$
CD	-1×35^2	$1\times 2\times 31$
Σ	–1325	290

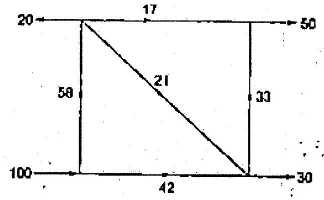


$$\Delta Q = -\left(\frac{-1325}{290}\right) = 5$$



and modify till $\Delta Q = 0$

So, the final discharges are as shown below



5.8 Appurtenances in Plumbing System

The plumbing system can be divided in two types

(i) Water supply system plumbing

(ii) Sanitary and drainage system plumbing

Appurtenances used in plumbing system includes Ferrules, goose neck pipe, service pipe, water meters, stop cock, water taps, bib cocks, spouts, pipe fittings such as bends, crosses, tees, elbows, unions, caps, plugs, flangs etc.

5.8.1 Ferrules

- Ferrules is a right angles 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 of the main is used to connect the service pipe leading to domestic connection.
- Its size generally various between 10 to 50 mm diameter.

5.8.2 Goose Neck

- Goose neck is a small curved flexible pipe for making connection between ferrule and service pipe.
- It is usually of about 75 cm length and made up of lead to provide flexiblity.
- 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.

5.8.3 Service Pipe

- This is a galvanised iron pipe of nominal size (internal diameter) less than 50 mm
- This is laid below ground level making a trench. It supplies water to individual buildings through the municipal main.
- This pipe is connected to the main through ferrule and goose neck.

5.8.4 Stop Cock

- This is provided before the water meter (if the water meter is provided). Otherwise, 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 stopping or opening the water supply to the premises.
- When water meter is provided then, both the water meter and stop cock is housed in the same chamber.

5.8.5 Water Meter

- Water meter are connected after the stop cock to measure the quantity of water supplied to a building.
- Water meter are classified according to the method of measuring flux. Mainly, there are two types of meters.
  - (i) Velocity or inferential meters
    - Such types of meters measure the horizontal velocity of water flowing through them.
    - They measure large flow and are often used by industries for measuring large supply.
    - They have an additional advantage of measuring water containing suspended particles.
  - (ii) Positive or Displacement Meters
    - They work by the flow of water causing a piston to reciprocate within a cylinder or communicating the movement finally to a system of dials, which register the quantity of flow.
    - Such type of meters are very bulky and heavy, hence, an improvement has been done and the improved ones are knows as semi-positive meters.
    - They are widely used for domestic supplies

The two most common type of semi positive meters are

(a) Rotary piston meters

(b) Nutating disc meters

In selecting a type of meter for a particular use, following points should be considered.

(a) Quantity of flow to be measured

(b) Nature of flow (whether continuous or intermittent)

(c) Permissible head loss (should not be more than 3 m)

(d) Cost (the inferential meters being less costlier)

5.9 Water Supply System Plumbing

- Water supply system plumbing includes provision of pipes and fitting including storage tanks in the premises.
- The first job for design of water supply plumbing system is to fix the position of different fitting in the plan of the building.
- Secondly, water requirement has to be fixed which gives an idea of diameter of pipe to be provided.
- And finally, after getting total discharge, diameter of service pipe is determined.
- For conveyance and distribution of water within the premises following points should be kept in mind.
  - (i) In designing and planning the layout of the pipe work, proper consideration should be given to the maximum rate of discharge, economy required in labour and material, protection against discharge and corrosion.
  - (ii) To reduce friction losses, inside of piping should be as smooth as possible. Methods of joining shall be such as to avoid internal roughness and projection at the joints.
  - (iii) Change in diameter and direction should be gradual.
  - (iv) All pipe work should be so designed, laid and fixed as to be completely water tight.

(v) Where the service pipe is of less then 50 mm diameter, the stop valves shall be of the screw-down type and shall have loose washer plates to act as non return valves. Other stop valves in the service line may be of the gate type.

(vi) The number of joints in the service pipe should be kept to a minimum.

(vii) Before the pipeline is charged i.e. water is allowed to flow, care should be taken to ensure that all piping and fittings are internally clean and free from particles of sand and soil, metal chips etc., which may obstruct flow and may help to accelerate corrosion.

5.10 Service Connection

The service pipe connection from a main to a property is usually laid down as shown in figure 5.5.

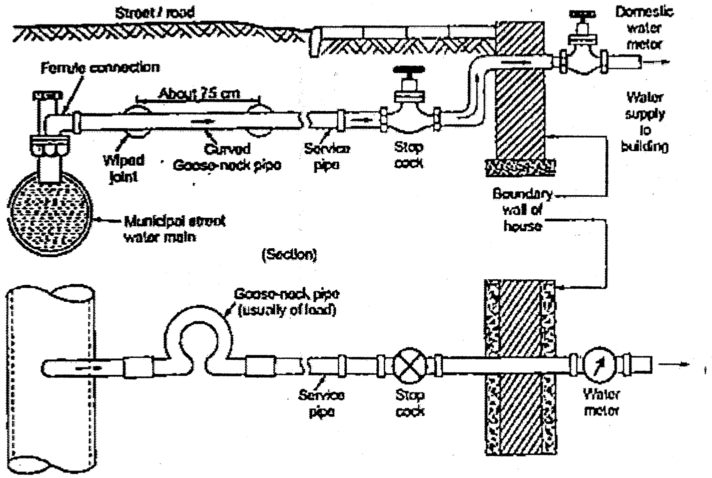


Fig. 5.5 Service Connection

- The ferrule is inserted in to the main by means of a under pressure tapping machines.
- Connection with ferrule to the service pipe is made through a flexible material pipe known as goose neck of about 75 cm in length.
- Service pipe is usually of galvanised iron pipe of size less than 50 mm diameter
- One stop cock is provided before the water enters the water meter in the home (if water meter provided). Otherwise, the stop cock is provided just before the pipe enters the house.
- The meter beyond the stop cock is fitted with unions to facilitate necessary periodic changing of the meters.
- Meters fitted in an exposed position outside building are in housed in water meter box conforming to I.S. 2104.

Example 5.5 Service connection consists of

(a) ferrule, stopcock and gooseneck
(b) ferrule, check valve and gooseneck
(c) stopcock, meter and sluice valve
(d) sluice valve, check valve and meter

Ans. (a)

5.11 Jointing

The concrete pipe lengths, flowing under gravity, can be easily joined with a mortar caulked bell and spigot joint, such as shown in given figure. For such gravity flows. This pipe has been developed in sizes of 0.6 m, to 1.8 m in diameter. A special pipe laying machine with a slip form is used. This No-joint pipe, though not reinforced, is yet found to have a good life. For high pressure pipes, a lock joint such a shown in the figure may be needed. For heads above 30 m or so, welded steel cylinder is often cast in the pipe for after tightness. The R.C.C pipe lengths are joined by placing the protruding end bars of different length butting against one another and welding them, and finally filling the gap with rich cement concrete, so as to provide a watertight joint.

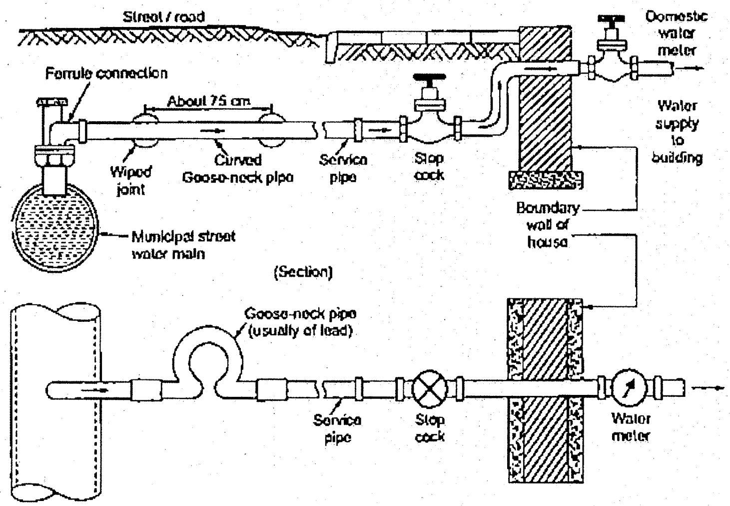


Fig. 5.6

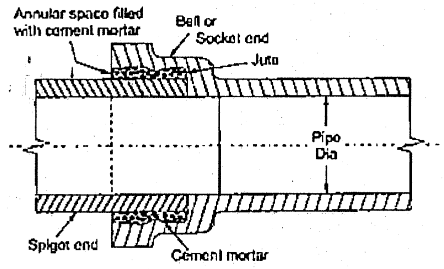


Fig. 5.7

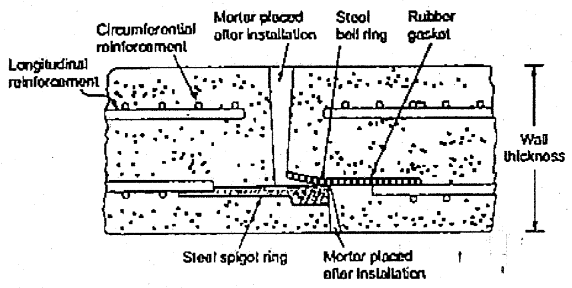


Fig. 5.8

5.12 Sewer Materials

Vitrified clay (or stone ware), cement concrete, asbestos cement and cast iron are the most common materials used for construction sewer pipes. While selecting a particular material for construction sewer pipes, the important factors which must be considered are:

(i) **Resistance to corrosion:** The sewer pipes are likely to be acted upon by sewer gases, and thus get corroded, due to the presence of acids and other impurities in sewage.

(ii) **Resistance to abrasion:** When the sewage contains a lot of grit and sand particles, moving at a high velocity at the sewer invert, a log of wear and tear of the sewer material may be caused due to abrasion. To avoid this erosion or wear and tear of the sewer pipes, the sewer material must be strong enough, so as to withstand such possible abrasions.

(iii) **Strength and durability:** The sewer pipes should be strong enough to withstand all the forces that are likely to come on them. Since they are laid well below the ground level, they are subjected to considerable external loads.

(iv) **Light weight:** The material used for sewers should be light, so that the sewers can be easily handled and transported.

(v) **Imperviousness:** The sewer material should be impervious as not to allow any seepage of the sewage from the sewer.

(vi) **The economy and cost:** The sewer material must be cheaper and less costly as to cause overall economy in their construction.

(vii) **Hydraulically efficient:** The sewer material should be such as to provide a smooth interior surface (with Manning's N as low as possible) so as to provide an hydraulically efficient surface.

Besides cement concrete, asbestos cement and vitrified clay which are the commonly used materials, other materials which may also be used for sewer constructions are bricks, cast iron and plastics. The sewers of different possible materials and their comparative utilities are described below:

1. **Asbestos cement sewers:** Asbestos cement pipes are manufactured from a mixture of asbestos fibre, silica and cement, converted under pressure to a dense homogeneous materials, possessing considerable strength, called asbestos cement. The asbestos fibre which is thoroughly mixed with cement serves as reinforcement, and provides a strong material. These pipe are normally available in sizes say from 10 to 90 cm in diameter and 4 metres in length.

Joining: These pipes can be easily assembled without skilled labour, with the help of a special coupling (called Ring Tie coupling or Simplex joint) as shown in figure (a). The assembly consists of a pipe sleeve and two rubber rings, which are compressed between the pipe and the interior of the sleeve. The joint is as resistant to corrosion as the pipe itself, and is flexible enough as to permit as much as 12° deflection, while laying the pipes around curves (in plan).

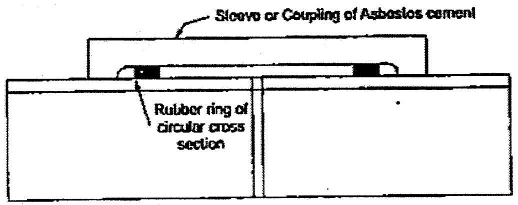


Fig. 5.9 Simplex joint for AC pipes

The advantages of AC pipes are:

(i) They are light in weight and hence easy to transport.

(ii) They can be easily cut and assembled without skilled labour.

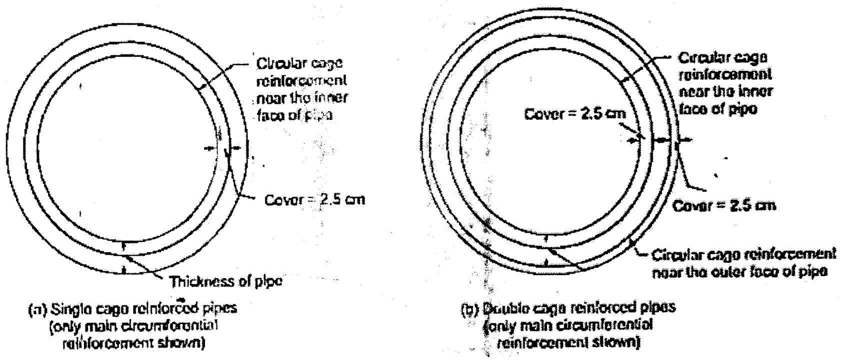
(iii) Their interior surface is exceptionally smooth (with Manning's N = 0.011), thus providing an excellent hydraulically efficient sewer.

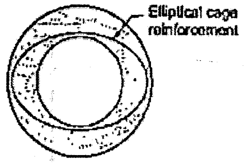
The disadvantages of AC pipe are:

(i) They are structually not strong enough to bear the huge compressive stresses induced by the heavy external loads to which the deeply buried sewers may be subjected to.

(ii) They are susceptible to corrosion by sulphuric acid from hydrogen sulphide gas generated in sanitary waste water or by some industrial chemicals. The sulphide corrosion of asbestos cement as well as cement concrete pipes is a big problem in areas where the sewage is strong, stale and very warm, because under such conditions the bacterial activity responsible for producing hydrogen sulphide gas gets accelerated. Hence in all such cases, vitrified clay (popularly called stone ware) pipes should be used for sewers of less than 1 m in diameter, and cement concrete pipes with cast insitu plastic linings may be used for larger diameter sewers.

2. **Plan cement concrete and reinforced cement concrete sewers:** Plain cement concrete pipes are manufactured in small sizes, while they are reinforced with steel reinforcement for larger diameter pipes. RCC pipes are easily available in sizes up to diameters say 1.8 metres, and may be got manufactured for larger diameters say upto about 4.5 metrs, on special orders.





(c) Elliptical cage reinforced pipes (only main circumferential reinforcement shown)

Fig. 5.10

These pipes may either be prepared at site by transporting ingredients (i.e., cement, steel aggregates, water, etc.) or can be manufactured in factories, and then transported to site. They are known as cast in situ pipes in the former case, and precast pipes in the latter case. Cast insitu pipes are useful when the site conditions are difficult and where it may be difficult to carry the pipes. But since such pipes are cast at site, lesser supervision and check is possible as compared to the case of precast pipes which are cast in the factories and thus subjected to greater quality control and supervision.

Reinforcement concrete (RCC) pipes are those concrete pipes which are provided with circumference reinforcement to carry internal or external stresses, and a nominal longitudinal reinforcement equal to 0.25% of the cross-sectional area of concrete. The circumferential reinforcement is generally provided in three different ways, as shown in figure 5.10 (a), (b) and (c).

The non-pressure RCC pipes are classified according to IS 458 : 1988 into the following three categories:

(i) **NP2 pipes:** They are light duty RCC non-pressure pipes, normally used for drainage and irrigation use, for culverts carrying light traffic. The thickness of NP2 pipes very from 25 mm for 8 cm dia. pipe to 110 mm for 2.2 m dia. pipe.

(ii) **NP3 pipes:** They are medium duty no-pressure pipes, normally used for drainage and irrigation use, for culverts carrying medium traffic. The thickness of NP3 pipes very from 25 mm for 8 cm dia pipe to 215 mm for 2.6 m dia. pipe.

(iii) **NP4 pipes:** They are heavy duty non-pressure pipes, normally used for drainage and irrigation use, for culverts carrying heavy traffic, such as railway loading.

The unreinforced as well as reinforced concrete pipes shall be capable of withstanding a test pressure of 7 m head of water.

RCC pressure pipes, classified as P1, P2 and P3 pipes, are generally used for carrying water supplies under pressure and are usually not used as sewers which are designed as gravity conduits:

RCC pipes can be manufactured in three different ways, viz.:

(a) Pipes having bar and mesh reinforcement, and concrete poured by usual ordinary methods or concrete pouring and tamped.

(b) Pipes made by rotating the mould or the form, rapidly about the pipe axis. The mould contains concrete and fabricated reinforcement. The centrifugal force throw of the concrete, which then spreads in a uniform layer over the internal surface of the mould and embed the reinforcement thus providing a high density water waterlight concrete surface. This type is known as centrifugal type.

(c) The third type of pipes are made by lining thin cylindrical steel shells, both internally and externally, with rich cement concrete. These are stronger and more waterlight than the first two. They are known as cylinder type.

Hume steel pipes are also the RCC pipes patented under this name, and consist of thin steel shells coated from inside with cement mortar by centrifugal process. The thickness of the inside coating varies from 12 mm to 30 mm depending upon the size of the pipe. They are also coated from outside, so as to protect the steel shell from external weather or soil action.

Advantages of concrete pipes are given below:

(i) All these different forms of cement concrete pipes are quite strong in tension (for withstanding internal pressures) as well as in compression (for withstanding external loads).

(ii) They are quite resistant to erosion and abrasion.

(iii) They can be easily moulded and manufactured either at site or in the factory.

(iv) They can be made of any desired strength by proper design and proportioning of concrete mixes.

(v) Their cast-insitu forms may be easily used at places where, owing to ground water or running sand conditions, brick sewers or cast at site concrete sewers can not be used.

(vi) They prove economical in medium and large sizes, and hence, widely adopted for branch and main sewers.

The biggest drawback of the concrete sewers, however, is the fact that they easily get corroded and pitted by the action of sulphuric acid produced from hydrogen sulphide gas (evolved from the stale sewage) or from such other chemicals present in sewage. This not only reduces the life span of the sewers but also reduces their carrying capacities with time. Besides corrosion, they are also susceptible to erosion by sewage containing too much silt and grit.

The concrete sewers can be protected from such actions by lining their interiors with vitrified clay linings, as shown in fig. The blocks of vitrified clay, for this purpose, are provided with projections, which project and enter the cement concrete as shown. The joint between adjacent blocks are filled either with rich cement mortar or with bituminous compounds.

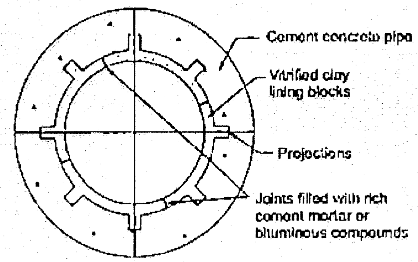


Fig. 5.11 Cement concrete pipe, lined inside with verified clay lining

Other methods of protecting concrete sewers from hydrogen sulphide corrosion are:

(i) Prohibiting the entry of wastes containing sulphides.

(ii) Reducing the sulphate contents by pre-treating the sewage.

(iii) Aerating and chlorinating the sewage.

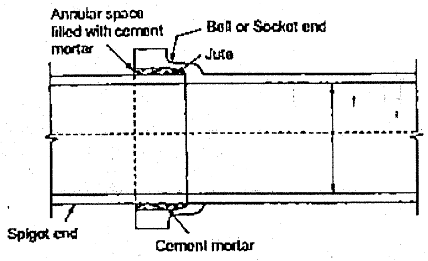
(iv) By adequately ventilating the sewers.

(v) By making the sewers to run full.

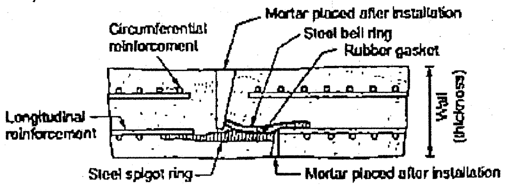
(vi) By adding such chemicals to sewage as may neutralise the already present sulphur compounds.

In view of its merits and drawbacks, the unlined cement concrete sewers are widely used for carrying storm water, which is comparatively free from organic impurities responsible for generating hydrogen sulphide gas. They may, however, be used for branch sewers bringing sewage free from industrial wastes. With protective linings, they are used for almost all the branch and main sewers.

Joining: The concrete pipe lengths, flowing under gravity, can be easily joined with a mortar caulked bell and spigot joint, such as shown in figure 2.12 (a). For such gravity flow. This pipe has been developed in size of 0.6 m to 1.8 m in diameter. A special pipe laying machine with a slip form is used. This No-joint pipe though not reinforced, is yet found to have a good life. For high pressure pipes, a lock joint such as shown in figure 5.12 (b) may be needed. For heads above 30 m or so, a welded steel cylinder is often cast in the pipe for water tightness.



(a) Bell and Spigot joint



(b) Joint for concrete pressure pipe

Fig. 5.12

The RCC pipe lengths are joined by placing the protruding end bars of different lengths butting against one another and welding them, and finally filling the gap with rich cement concrete, so as to provide a watertight joint.

3. **Vitrified clay or stone ware or salt glazed sewers:** Vitrified clay pipes are widely used for carrying sewage and drainage, as house connections as well as lateral sewers. They are available in size of 5 cm increments from 10 to 30 cm, and in 7.5 cm increments from 30 cm to 90 cm. They are, however, rarely made in sizes bigger than 90 cm diameter.

These pipes are manufactured from clays and shales of special qualities, which are, first of all, pulverized and mixed thoroughly with water. This mixture is then used for casting standard pipe sections in a pipe press at a pressure of about 8.5 kg/cm^2. These moulded pipe sections are dried in warm air, and then burnt in hot kilns under controlled temperatures. The temperatures of the kiln is maintained at about 150°C, in the beginning for several hours, and then raised to about 700°C, and finally to about 1200°C, when fusion or vitrification of clay takes place. This makes it very dense and hard. Near the end of the burning period, sodium chloride (i.e., common salt) is placed in the kiln. The intensive heat causes the salt to vaporise, which reacts with the clay, forming a thin smooth, hard, and a waterproof glazed layer on the pipe surfaces. These pipes are joined by a bell and a spigot flexible compression joint, in which the precision mated surfaces are in tight contact with one another. These pipe lengths are, therefore, cast with having bell and spigot ends, in lengths of about 0.9 to 1.2 m. The interior surface of the socket end and the exterior surface the spigot end, are, however, not glazed so as to make a watertight joint.

The advantages of these pipes are:

(i) The stoneware pipes offer the maximum advantages of being highly resistant to sulphide corrosion, and therefore, preferred for carrying polluted sewage and industrial wastes.

(ii) Their interior are very smooth and they are hydraulically very efficient.

(iii) They are highly impervious and do not allow any sewage to very efficient.

(iv) They are, though weak in tension, yet quite strong in compression, and hence they are quite suitable for withstanding compressive stresses caused by traffic and back fills.

They, however, can withstand only very small tensile stresses caused by internal pressures. Hence, they can, through withstand slight tensile stresses caused by some chancy surcharge of gravity sewers, yet cannot be used as sewers flowing under pressure.

(v) These pipes are quite cheap, durable, easily available, and can be easily laid and joint.

(vi) They are made, non absorbent, so as not to absorb water more than 5% of their own weight, after kept immersed in water for 24 hours.

The disadvantages of these pipes are:

(i) They are heavy, bulky, and brittle, and, therefore, difficult to transport. Due to this reason, they are cast only in smaller sizes and smaller lengths. Due to their shorter longths, numerous joints are required in laying such pipes, and due to smaller sizes, they cannot be utilized as branch or main sewers.

(ii) They cannot be used are pressure pipes, because they are weak in tension.

4. **Brick sewers:** Bricks had been used as sewer material since ancient days. They, however, have now-a-days been almost replaced by cement concrete sewers. However, they may still be used at places where the sewers are required to the constructed at the site and ingredients required for cement concreting may not be easily available. They may also be preferred for constructing large sized combined sewers, or particularly for storm water drains.

Brick sewers are generally plastered on their outer surfaces so as to prevent the entry of tree roots and ground water through the brick joints; and are lined inside with stone ware or ceramic block so as to render them smooth and hydraulically efficient. The stoneware or ceramic coating also helps in resisting sulphide corrosion which is not possible with the ordinary cement plaster as the same is easily attacked by sewer gases like hydrogen sulphide.

5. **Cast Iron sewers:** Cast iron pipes are structurally stronger and capable of withstanding greater tensile, compressive, as well as bending stresses, but are costlier, compared to cement concrete or stone ware pipes. They are therefore, used as sewers, only under special circumstances, such as:

(i) For outfall sewers, for rising mains of pumping stations, or for inverted siphons, all running under pressure.

(ii) For sewers to be laid below heavy traffic loads, such as those laid below highways or railways.

(iii) For sewers which are to be 100% leak proof, so as to avoid possible contamination of under ground water supplies.

Cast iron pipes are through structurally quite stronger and durable, yet can not withstand the corrosive action of gases and other acids present in sewage; and hence generally lined from inside with cement concrete, or painted with coal tar, etc. Although the sewer pipes are not subjected to high pressures, but still they are made as heavy or even heavier than the water pipes, so as the resist the corrosive action of sewage.

6. **Lead sewers:** The lead pipes are smooth, soft, and can be easily bent to take odd shapes. They are also not affected by acid or alkaline sewage discharges, and can resist sulphide corrosion. They are, however, very costly.
   The lead pipes are occasionally used in smaller sizes (3 to 4 cm diameter) and in smaller lengths in the toilets. The may be used as a downtake pipes of flushing cisterns, or as waste pipes from stall urinals and wash basins, or for geyser connections.
7. **Plastic sewers:** The use of plastics for non-pressure sewer pipes is of comparatively recent origin, and is still in the experimental stages. Yet however, certain countries like Netherlands, Scandinavia, France, etc. have already started using plastic pipes for sewers of 250 mm dia and above, on a moderate to large scale (15% to 25% or so). Their use in Germany and U.K. is hardly 5-7%, and in India, practically no plastic pipes are used for sewers, although of course, they are, finding increasing use in internal water supply and drainage fittings.

5.14 Water Storage for Buildings

In a building, provision should be made:

(a) For storage of water
(a) To reduce the maximum rate of demand on the main
(b) To tide overperiods of intermittent supply.

- Water storage tank may be placed at the roof of the building or an underground tank is made.
- Water to the tank placed on roof top is supplied through pumps.
- Over head tanks are constructed of iron, wrought iron or mild steel plates and should be perfectly water tight without the use of any sealing materials.
- Underground tanks are mostly made of RCC.

Capacity of storage tank depends on following factors:

(i) Hours of supply at sufficient high pressure to fill up the overhead storage tank
(ii) Rate and regularity of supply
(iii) Frequency of replenishment of tanks during the 24 hours

If the water supply is intermittent and hours of supply are irregular, it is desirable to provide minimum storage capacity equal to half a days supply for the overhead tanks.

5.15 Design of Balancing Reservoir/Distribution Reservoir/Service Reservoir

- The main and primary function of a distribution reservoir is to meet the fluctuating demand with a constant rate of supply.
- The quantity of water required to be stored in the reservoir for equalising or balancing this variable demand against the constant supply is known as the balancing reservoir or balancing storage or the storage capacity of a balancing reservoir.
- This storage capacity of balancing reservoirs is worked out with help of hydrographs of inflow and outflow by mass curve method or by analytical tabular solution.

(a) Mass Curve Method

- A mass curve diagram is the plot of accumulated supply or demand versus time.
- The supply is also called as inflow and demand as outflow. First mass curve of supply known as supply line is drawn and over this demand curve is superimposed.
- The amount of balancing storage is determined by adding the maximum ordinates between the demand and supply lines.
- To construct such diagram for a particular water supply project, we have to proceed as follows.

(a) From the past records, determine the hourly demand (or draft) for all 24 hours for typical days (maximum, average and minimum).
(b) Calculate and plot the cumulative demand against time and then plot the mass curve of demand.
(c) Draw the cumulative supply also against time, which is a straight line if the supply is constant.
(d) The storage required is calculated as the sum of the two maximum ordinates between demand and supply lines.
(e) Repeat the procedures for all the typical days (maximum, average and minimum) and determine the maximum storage required for the worst days.

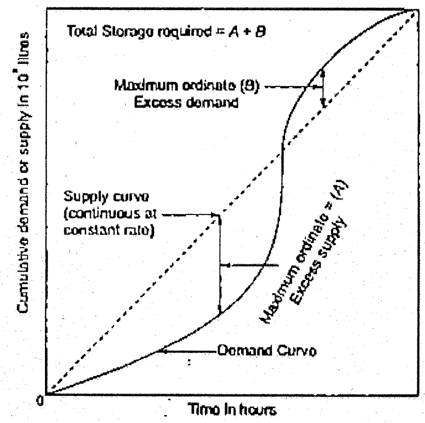


Fig. 5.13 Continuous Supply

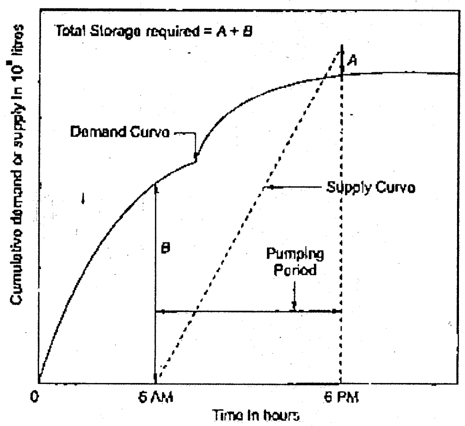


Fig. 5.14 Limited Hour Supply

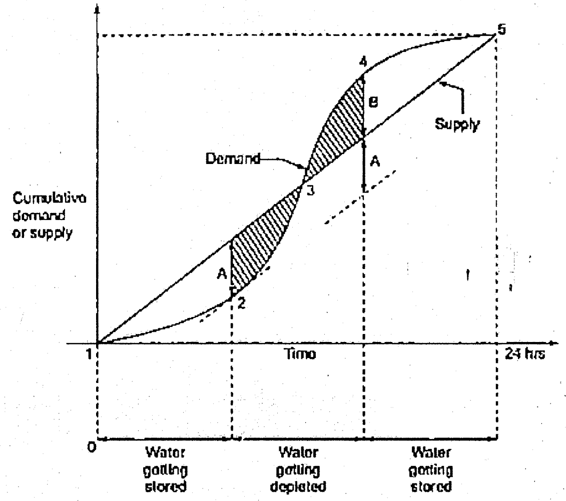


Fig. 5.15 Limited Hour Supply

From (2 - 4) → Demand rate > supply rate
→ Water getting depleted
From (4 - 5 - 1 - 2) → Demand rate < supply rate
→ Water getting stored
From (4 - 5) → Accumulation = *B*
From (1 - 2) → Accumulation = *A*
From (2 - 3) → Depletion = *A*
From (3 - 4) → Depletion = *B*

⇒ Maximum water that would be accumulated = *A* + *B* (i.e From 4 - 2)

⇒ Maximum water that would be depleted = *A* + *B* (i.e From 2 - 4)

Example 5.6 The purpose of providing a balancing reservoir in a water supply distribution system is to

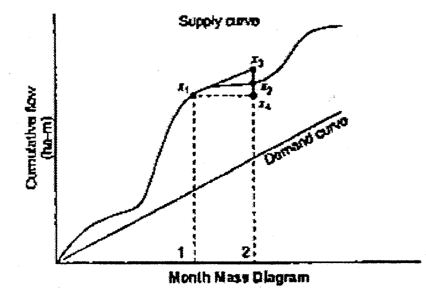
(a) equalize pressures in the distribution system
(b) stores adequate quantity of water to meet requirements in case of breakdown of inflow
(c) store adequate fire fighting reserve
(d) take care of fluctuations in the rate of consumption

Ans. (d)

Example 5.7 In the figure shown below, x_2x_4 represents

(a) accumulated supply (b) storage requirement
(c) accumulated demand for the period 1 to 2 (d) surplus in the reservoir

Ans. (a)



(b) Analytical Method

In analytical method cumulative hourly demand and cumulative hourly supply are tabulated for all the 24 hours. The hourly excess demand and hourly excess supply are worked out. The summation of maximum of the excess of demand and the maximum of excess of supply gives the required storage capacity.

Example 5.8 Calculate the storage required to supply the demand shown in the following table if the inflow of water to the reservoir is maintained at a uniform rate throughout 24 hours.

Time	Demand in Million litres
00 - 04	0.48
04 - 08	0.87
08 - 12	1.33
12 - 16	1.00
16 - 20	0.82
20 - 24	0.54

Solution:

Total demand during the day = 0.48+0.87+1.33+1.0+0.82+0.54
= 5.04 million litres

Total supply during the day = Total demand = 5.04 million litres

Constant hourly supply = $\frac{5.04}{24} = 0.21\ Ml$

Now, 4 hourly supply = $0.21 \times 4 = 0.84\ Ml$

Time in hour	Demand in Ml	Cum demand in Ml	Supply in Ml	Cum Supply in Ml	Excess of demand (col. 3 - col 5) (+ve values only)	Excess of supply (col. 5 - col 3) (+ve values only)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0 - 4	0.48	0.48	0.84	0.84	—	0.36
4 - 8	0.87	1.35	0.84	1.68	—	0.36
8 - 12	1.33	2.68	0.84	2.52	0.16	—
12 - 16	1.00	3.68	0.84	3.36	0.32	—
16 - 20	0.82	4.50	0.84	4.40	0.10	—
20 - 24	0.54	5.04	0.84	5.04	—	—

From above table, it is observed that the maximum of excess of demand = 0.32 *Ml* and the maximum of excess of supply = 0.36 *Ml*.

Therefore, total storage required = 0.32 + 0.36 = 0.68 *Ml* = 680,000 litres

Example 5.9 For a town daily requirement of water for supply to the population is 2 lakh litres. The pattern of draw off is as follows.

6 a.m to 9 a.m - 30% of day's supply
9 a.m to 4 p.m - 35% of day's supply
4 p.m to 7 p.m - 25% of day's supply
7 p.m to 6 a.m - 10% of day's supply

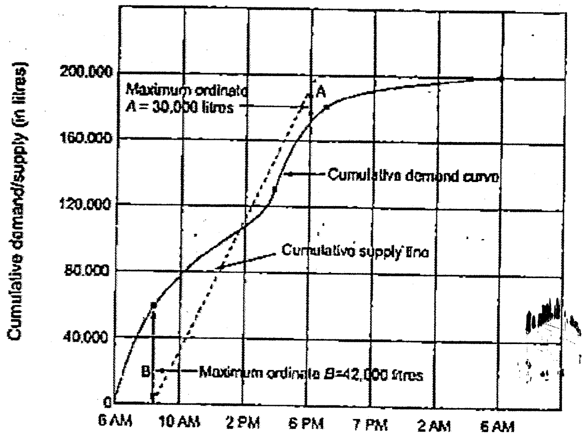
The pumping is done for 10 hours a day from 8 a.m to 6 p.m. Find out the storage capacity of the distribution reservoir for the water supply scheme.

Solution: Total daily requirement = 200,000 litres

Now, the cumulative demand covered is tabulated in the table given below:

Period	Rate of Demand	Demand in Litres	Cumulative Demand
6 a.m. to 9 a.m.	30% to 2 lakh litres	60,000	60,000
6 a.m. to 4 p.m.	35% to 2 lakh litres	70,000	130,000
4 p.m. to 7 p.m.	25% to 2 lakh litres	50,000	180,000
7 p.m. to 6 a.m.	10% to 2 lakh litres	20,000	200,000

The mass curve of demand has been plotted in figure.



Total demand is met in 10 hours

∴ Rate of supply = 200,000/10 = 20,000 litres/hr

Two maximum ordinates between supply and demand lines are

A = 30,000 litres; B = 42,000 litres

Now, Total storage capacity = A + B = 72,000 litres

Illustrative Examples

Example 5.10 An overhead tank is to be provided for a town water supply. Given the following data, calculate the minimum capacity of the tank without any fire demand. Tank is empty between 12 to 15 hours. (a) Rate of pumping = 25,000 litres/hr, (b) Hours of pumping = 4 to 12 and 15 to 23 hrs

No.	Time (hr)	Hours	Water pumped	Water demanded
1	0 - 4	4	0	13,333
2	4 - 6	2	50,000	40,000
3	6 - 10	4	100,000	120,000
4	10 - 12	2	50,000	33,333
5	12 - 15	3	0	25,000
6	15 - 16	1	25,000	8,333
7	16 - 20	4	100,000	106,666
8	20 - 23	3	75,000	50,000
9	23 - 24	1	0	3,335

Solution: Problem has been solved analytically in table given below.

As given in the question, the tank is empty between 12 and 15 hours. Hence, we shall start from Sl. No. 5. At Sl. No. 6 storage is (+) 16,666 again at S. No. 7, it has reduced by 6666 litres. Hence, net storage is (16000 – 6666) = 10000 and so on proceed Sl. No. 8, 9, 1, 2, 3 and finally at 4.

Serial No.	Time	Hours	Water pumped (litres)	Water demanded (litres)	Accumulation (+) draw off col. 4 - col. 5	Water in service reservoir in (litres)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	0 - 4	4	—	13,333	(–) 13,333	18,333
2	4 - 6	2	50,000	40,000	(+) 10,000	28,333
3	6 - 10	4	100,000	120,000	(–) 20,000	8,333
4	10 - 12	2	50,000	33,333	(+) 16,667	25,000
5	12 - 15	3	0	25,000	(–) 25,000	0
6	15 - 16	1	25,000	8,333	(+) 16,667	16,667
7	16 - 20	4	100,000	106,666	(–) 6,666	10,001
8	20 - 23	3	75,000	50,000	(+) 25,000	35,001
9	23 - 24	1	0	3,335	(–) 3,335	31,666

Now, from column no 7, it is clear that maximum balance storage is 35,001 litres. Hence, capacity of the tank should be 35,001 litres.

Example 5.11 A service water tank is receiving water from the treatment plant at a rate of 200 m^3/hr for 24 hours. The high lift pumps are lifting water from the same tank at following rates: 4 - 14 hrs @ 120 m^3/hr and 15 - 24 hrs @ 400 m^3/hr. Determine the capacity for the service water tank.

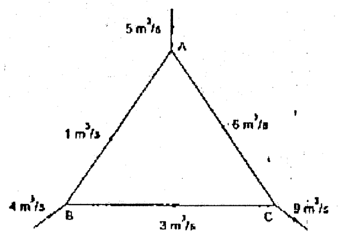
Solution: The problem has been solved in the table given below.

The cumulative supply over demand i.e.. excess supply to the tank is 1800 m^3. Hence, the capacity of the tank should be 1800 m^3.

Time in hour	Demand from clear water tank lifted by high lift pumps (m^3)	Cumulative demand from clear tank pumps (m^3)	Supply in the clear water tank (m^3)	Cumulative Supply (m^3)	Accumulation(+) draw off (–) col. 5 - col. 3
(1)	(2)	(3)	(4)	(5)	(6)
0 - 4	Nil	Nil	200 × 4 = 800	800	(+) 800
4 - 14	120 × 10 = 1200	1200	200 × 10 = 2000	2800	(+) 1600
14 - 15	Nil	1200	200 × 1 = 200	3000	(+) 1800
15 - 24	400 × 9 = 3600	4800	200 × 9 = 1800	4800	0

Example 5.12 A pipe network in the form of a triangle *ABC* has inflows of 5 m^3/s and 4 m^3/s at *A* and *B* respectively. The outflow at *C* is 9 m^3/s. Given K_{AB} = 10, K_{BC} = 50, K_{AC} = 20, compute discharges in each pipeline $[h_f = KQ^2]$.

Solution: First of all, the magnitudes as well as directions of the possible flows in each pipe are assumed keeping in consideration the law of continuity at each junction. The assumed flows are given in the figure shown below:



It is given that $h_f = KQ^2$

The given pipe network can be analysed by Hardy Cross method.

1st iteration for the loop *BACB*

Pipe	Assumed flows Q_a	K	$H_L = KQ_a^2$	$\left\lvert\frac{H_L}{Q_a}\right\rvert$	Corrected Q after first correction $Q_{a_1} = Q_a + \Delta$
BA	1	10	10	10	0.5
AC	6	20	720	120	5.5
CB	–3	50	–450	150	–3.5
			ΣH_L = 280	$\sum\left\lvert\frac{H_L}{Q_a}\right\rvert$ = 280	

$$\Delta = -\frac{\Sigma H_L}{2\sum\left\lvert\frac{H_L}{Q_a}\right\rvert} = -\frac{280}{2\times 280} = -0.5 \text{ m}^3\text{/s}$$

2nd iteration for the loop *BACB*

Pipe	Assumed flows Q_a	K	$H_L = KQ_a^2$	$\left\lvert\frac{H_L}{Q_a}\right\rvert$	Corrected *Q* after second correction $Q_{a_1} = Q_a + \Delta$
BA	0.5	10	2.5	5	0.5086
AC	5.5	20	605	110	5.5086
CB	–3.5	50	–612.5	175	–3.4914
			ΣH_L = –5	$\sum\left\lvert\frac{H_L}{Q_a}\right\rvert$ = 290	

$$\Delta = -\frac{\Sigma H_L}{2\sum\left\lvert\frac{H_L}{Q_a}\right\rvert} = -\frac{-5}{2\times 290} = 0.0086 \text{ m}^3\text{/s}$$

Now, thus the discharges in pipe BA, AC and CB are 0.5086 m^3/s, 5.5086 m^3/s and 3.4914 m^3/s respectively.

Important Expressions

1. In Hardy-Cross method: Loss of Head, $h_f = rQ^n$
   Where, Q = flow of water; r = Proportional constant (which is different for different pipe)
2. Modification in discharge; $\Delta Q = \frac{(-)\sum rQ^n}{\sum\lvert mQ^{n-1}\rvert}$

Summary

- In continuous supply system, the rate of supply can kept low and pressure may be also low because in such conditions wastage of water through leakage takes place and lesser size of distribution pipes make the system economical.
- 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°. Crosses are provided to divert the flow in four direction whereas bends are provided to run the direction of the pipe line at a desired angle. Nippons are used to reduce the section of a pipe and unions are used to change a section of pipe when required.

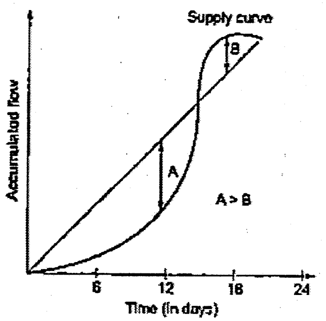
Objective Brain Teasers

Q.1 Sonoscope is used for which one of the following?
(a) Checking the accuracy of water meters
(b) Regulating the fire hydrants
(c) As a replacement of venturimeter for discharge measurement
(d) Detection of leakage in underground water mains

Q.2 Consider the following units associated in water supply system:
1. Pumping of raw water
2. Intake works
3. Treatment works
4. Distribution

The sequence of these units in the order of their connections starting from the source (river) is
(a) 1, 2, 3, 4 (b) 2, 1, 3, 4
(c) 2, 1, 4, 3 (d) 1, 2, 4, 3

Q.3 Consider the given figure of mass curve for estimating the storage capacity of the water supply tank. The storage capacity of the tank would be



(a) A (b) B
(c) $A - B$ (d) $A + B$

Q.4 Consider the following pairs:
1. Darcy Weisbach Equation ... $V = C\sqrt{RS}$
2. Manning's Equation ... $V = \frac{1}{n}R^{2/3}S^{1/2}$
3. Hazen William Equation ... $V = kCR^{0.63}S^{0.54}$
4. Chezy's Equation ... $\frac{h_l}{L} = \frac{f}{d}\left(\frac{V^2}{2g}\right)$

Which of these pairs are correct?
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

Q.5 A sudden change in the slope of the hydraulic gradient line drawn for a straight section of a water pipe line indicates the
(a) change in ground slopes
(b) presence of water hammer
(c) accumulation of sediments
(d) leakage in pipe line

Q.6 For the analysis of flow in a water distribution network, the site engineers prefer which of the following head loss equation?
(a) Darcy-Weisbach equation
(b) Chezy's equation
(c) Hazen-William's equation
(d) Manning's equation

Q.7 The estimated hourly consumption of water for a town at 9th hour is 6.10 million litres per hour Pump can supply water at a uniform rate of 1.5 m^3/s. Water required to be augmented from a storage reservoir in million litres per hour is
(a) 6.1 (b) 1.6
(c) 5.4 (d) 0.7

Q.8 Why are gate valves provided in distribution system.
(a) To minimize the flow pressure in the network.
(b) To maximize the usage of the distribution system.
(c) To control the flow in the pipe network.
(d) To identify the loss through illegal connections.

Q.9 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. improve power factor
B. reduce the current ripples
C. increase the power flow in line
D. reduce the Ferranti effect

List-II
1. shunt reactor
2. shunt capacitor
3. series capacitor
4. series reactor

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	2	4	1	3
(c)	3	1	2	4
(d)	2	1	4	3

Q.10 Which one of the following is the purpose of providing a surge tank in a pipeline carrying water?
(a) To store water
(b) To increase the pressure throughout the pipeline
(c) To store overflowing water
(d) To protect the pipeline against water hammer

Q.11 Match List-I (Type of Pipe) with List-II (Purpose) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Steel pipe	1. House plumbing
B. Cast iron pipe	2. Hot water carrying
C. GI pipe	3. Distribution main
D. PVC pipe	4. Pumping main

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	4	3	2	1
(c)	2	1	4	3
(d)	2	3	4	1

Q.12 The usual size of residential ferrule bore varies from
(a) 1 mm to 5 mm
(b) 10 mm to 50 mm
(c) 100 mm to 500 mm
(d) 1000 mm to 5000 mm

Q.13 Consider the following statements:
In water supply distribution network.
1. the gridiron system requires more length of pipe lines and larger number of cutoff valves.
2. the design of the gridiron system is difficult but economical
3. employing a grid iron system, the dead ends are completely eliminated
4. employing a gridiron system permits more water to be diverted towards the affected point from various directions.

Which of these statement are correct?
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 3

Q.14 Match List-I (Layout) with List-II (Suitable for) and select the correct answer using the codes given below the lists:

List-I
A. Tree system
B. Grid iron system
C. Ring system
D. Radial system

List-II
1. Satisfactory water supply, but not much used in India
2. Well-planned sector of city
3. For towns with rectangular road layout
4. For irregularly developed towns

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	4	1	2	3
(c)	2	1	4	3
(d)	4	3	2	1

Q.15 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Release valve
B. Check valve
C. Gate valve
D. Pilot valve

List-II
1. Reduce high inlet pressure to lower output pressure
2. Limit the flow of water to single direction
3. Remove air from the pipeline
4. Stopping the flow of water in the pipeline

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	4	2	1	3
(c)	3	4	2	1
(d)	1	2	4	3

Directions: The following items consists of two statements; one labelled as 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.16 Statement (I): Location of the elevated service reservoir (ESR) at the centre of the distribution area is helpful in equitable distribution of water to the consumers even when the distribution area is large.

Statement (II): For equitable distribution of water to the city, sufficient number of ESRs shall be provided to limit the area to be served by each of the ESRs.

Q.17 Statement (I): At the ferrule point of a water supply distribution pipe network for Indian towns having a majority of two-storey buildings, the ideal minimum pressure head of water is 12 m.

Statement (II): This magnitude of pressure head at ferrule is necessary to reach the highest floor of the two storey buildings.

Answers

1. (d)	2. (b)	3. (d)	4. (b)	5. (d)
6. (c)	7. (d)	8. (c)	9. (c)	10. (d)
11. (b)	12. (b)	13. (b)	14. (d)	15. (a)
16. (b)	17. (a)			