Civil Engineering

Environmental Engg : Vol-I

(Water Supply Engineering)

Comprehensive Theory

with Solved Examples and Practice Questions

MADE EASY Publications

MADE EASY Publications

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 011-45124660, 8860378007
Visit us at: www.madeeasypublications.org

Environmental Engineering : Vol-I (Water Supply Engineering)

Sixth Edition: 2020

Contents

Environmental Engg : Vol-I
(Water Supply Engineering)

Chapter 4

Treatment of Water.....112

Chapter 5

Distribution System.....228

■■■■

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.

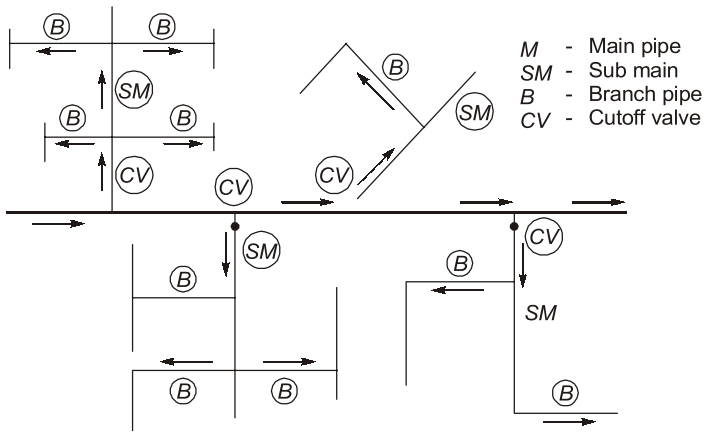


Fig. 5.1 Dead End System

- 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 rectangular 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.

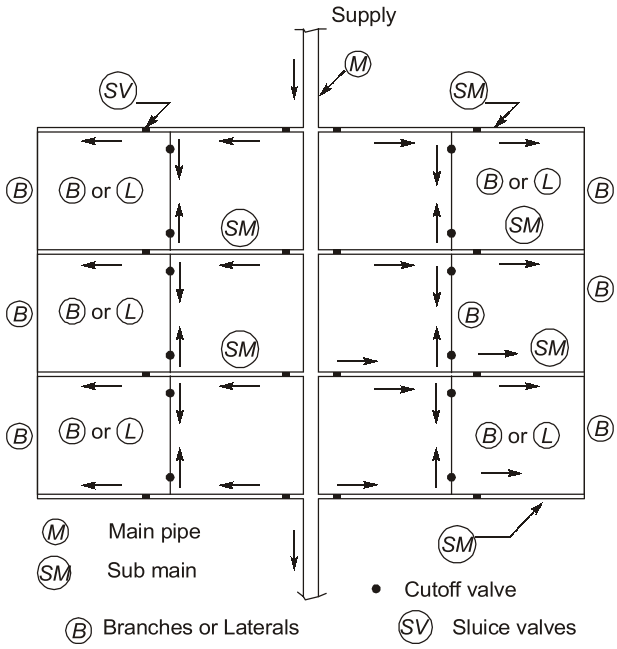


Fig. 5.2 Grid System

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.

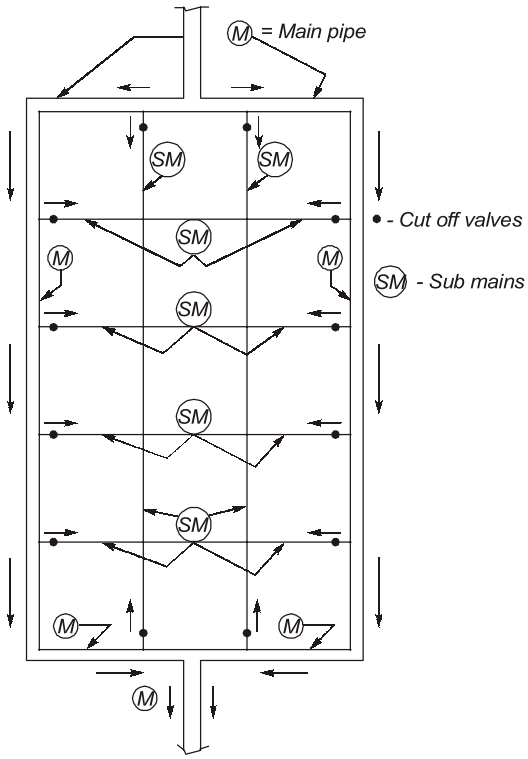


Fig. 5.3 Ring System

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

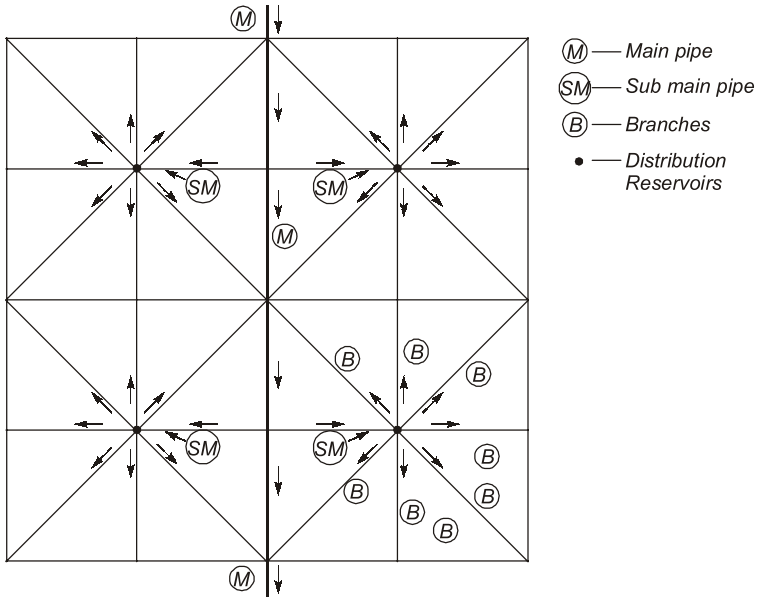


Fig. 5.4 Radial System

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 underground 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	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.

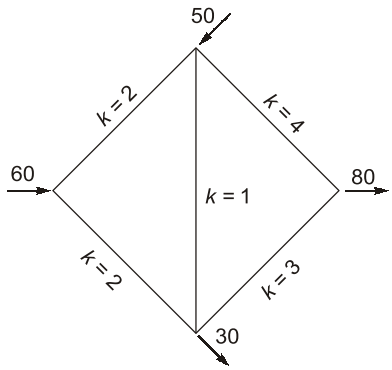
Here, loss of head is $h_L = rQ^n$

Steps

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

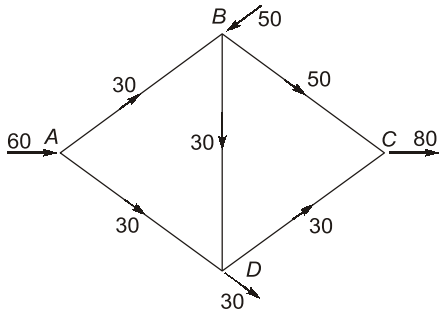
- The direction of h_L is same as discharge
  Clockwise discharge is taken as +ve h_L
  Anticlockwise discharge is taken as – ve h_L

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*:

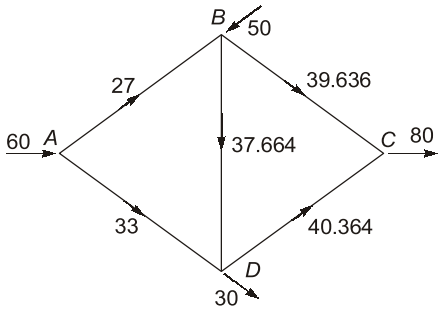
Pipe	Assumed flow Q	k	$h_L=kQ^2$	$[h_L/Q]$	Corrected flow
AB	30	2	1800	60	27
BD	30	1	900	30	27 + 10.364 = 37.364
DA	–30	2	–1800	60	–33
			Σ = 900	Σ = 150	

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

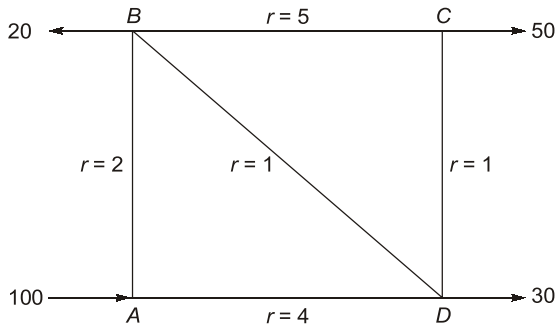
Loop *BCDB*:

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	

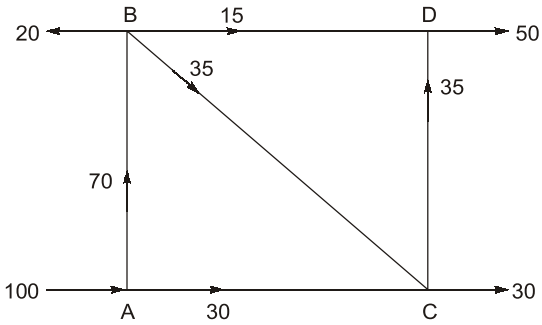
$$\Delta_2 = -\frac{6571}{2\times 317} = -10.364$$



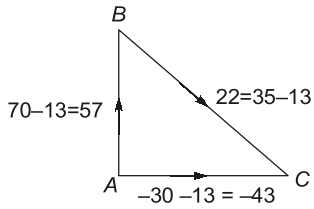
Example 5.4 Find the discharge through each pipe in the network of pipe shown below: (Take $n = 2$)



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

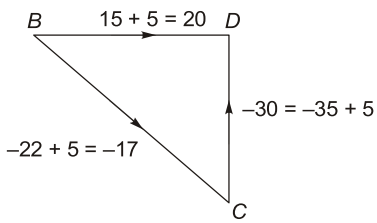


$$\Delta Q = \frac{-7425}{590} = -13$$

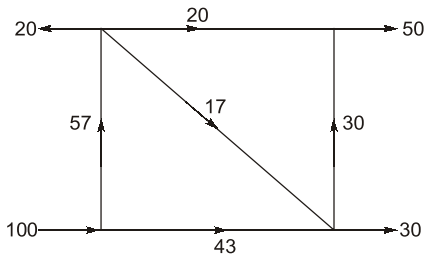
Considering Loop BCD

$\Rightarrow$

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

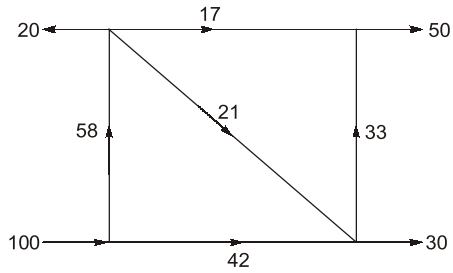


$$\Delta Q = -\left(\frac{-1325}{290}\right) = 5$$



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, flanges 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 tree 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 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.

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) Notating 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 than 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.

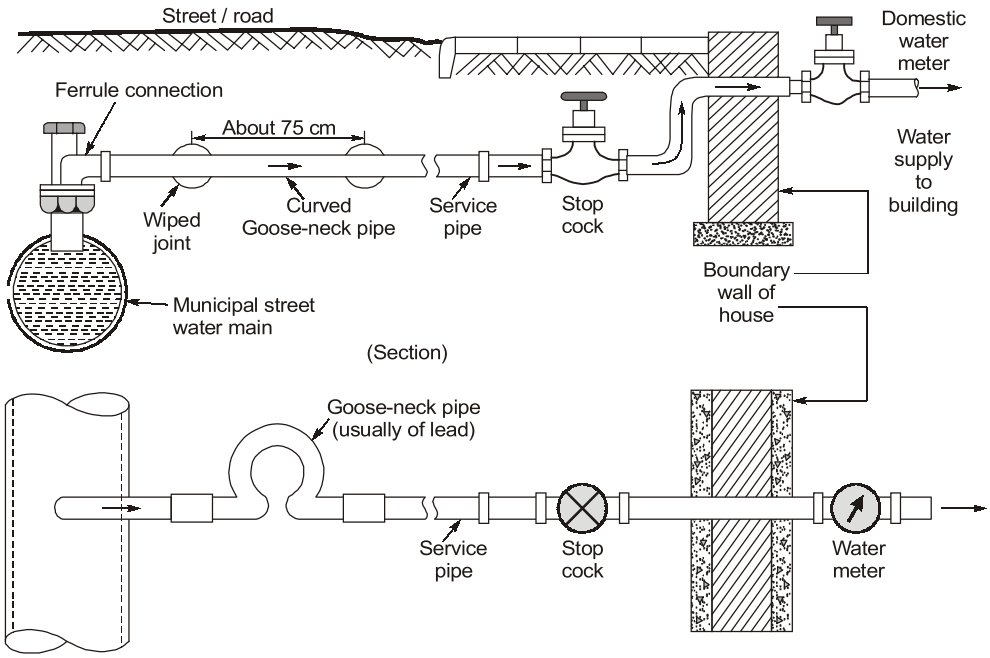


Fig. 5.5 Service Connection

- 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)

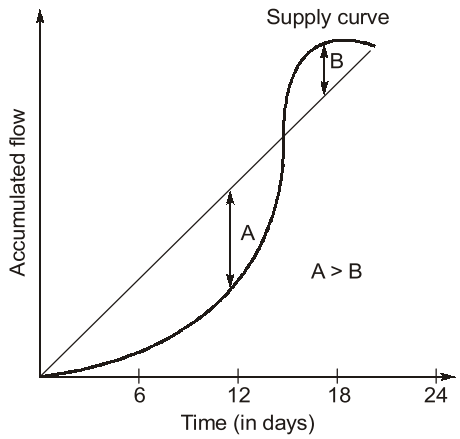
Objective Brain Teasers

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 ... $\frac{h_f}{L} = \frac{f}{d}\left(\frac{V^2}{2g}\right)$

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.