UPPSC-AE 2020

Uttar Pradesh Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Civil Engineering

Environmental Engineering

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Environmental Engineering

Contents

❍❍❍❍

CHAPTER 5

Distribution System

5.1 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.

5.2 Methods of Distribution

Water is forced in the distribution system in the following ways

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

I. 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.

II. 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

III. 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.

5.3 Systems of Supply

There are two system of supply of water

(i) Continuous supply

(ii) Intermittent supply

I. 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.

II. 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.

5.4 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

I. 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.

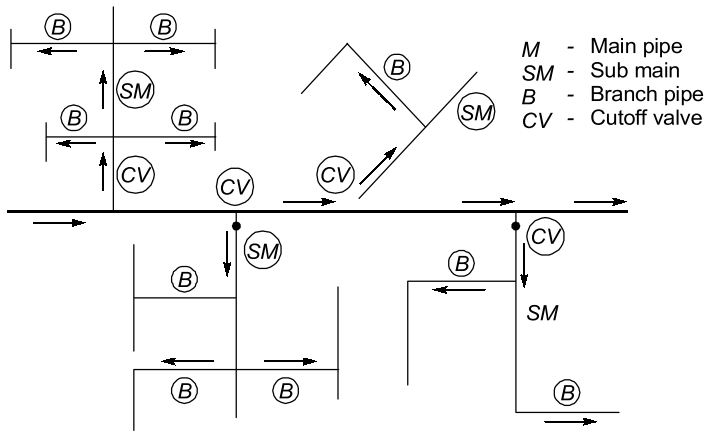


Fig. 5.1 Dead End System

- 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.

II. 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.

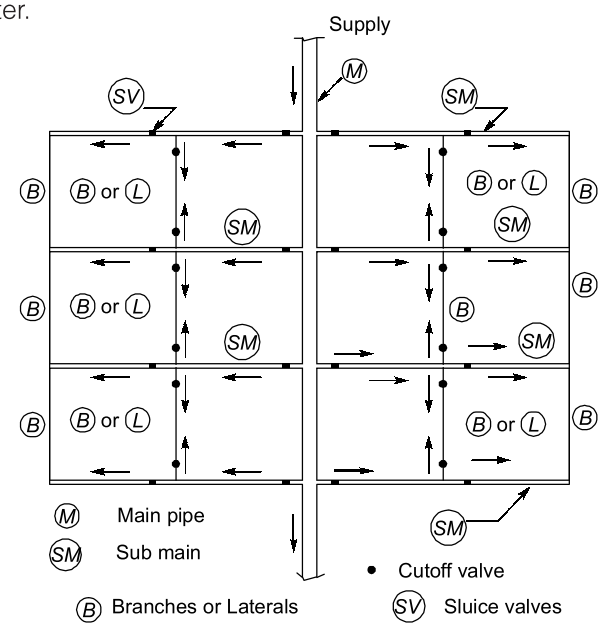


Fig. 5.2 Grid System

III. Ring System

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

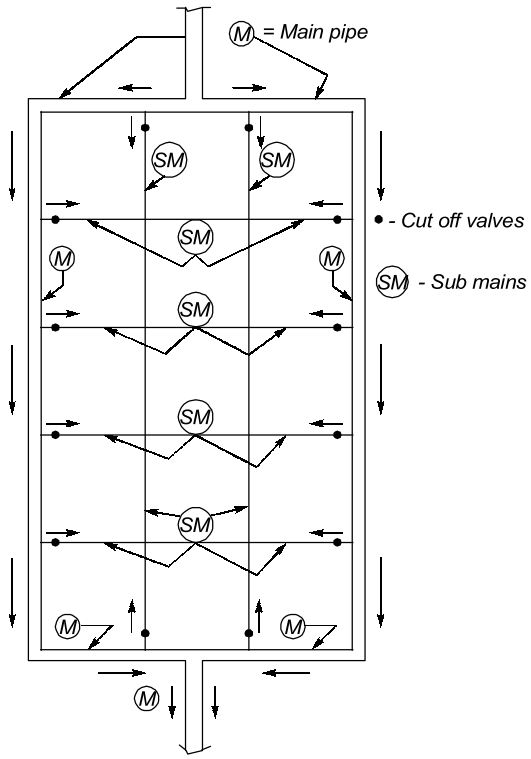


Fig. 5.3 Ring System

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

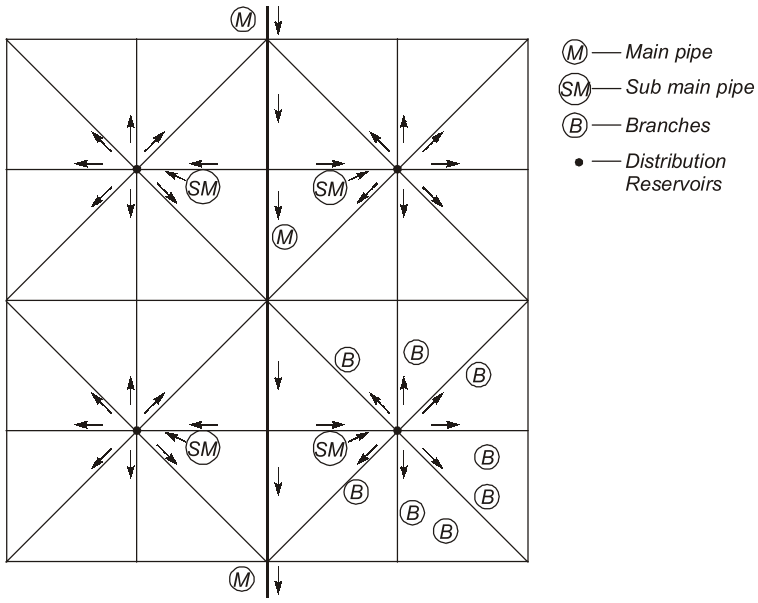


Fig. 5.4 Radial System

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)

5.5 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.

I. 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.

II. 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.

III. 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)

5.6 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.

Residential Districts

up to 3 storey	:	2 kg/cm^2
3 to 6 storey	:	2 to 4 kg/cm^2
6 to 10 storey	:	4to5.5 kg/cm^2
Commercial districts	:	5 kg/cm^2

A minimum velocity of 0.6 m/sec should be maintained.

NOTE : The greater is the design pressure the costlier it will be but will cause more convenience to the consumers.

Manual of Water Supply Recommends

Residual pressures at Ferrule point:

Single storey building	—	7 m
two storey building	—	12 m
Three storey building	—	17 m

Distribution system should not ordinarily be designed for residual pressures exceeding 22 meters. Multi storeyed buildings needing higher pressure should be provided with boosters.

Minimum Pipe sizes

Manual recommends:

Town with population up to 50,000:100 mm diameter.

Town with population > 50000 : 150 mm diameter.

NOTE : Pressure in excess of 70 m in the distribution system are generally undesirable and maximum allowable pressure is of the order of 100 m, which generally equals the design pressure for plumbing fixtures, like pipe fittings etc.

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

I. 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.

II. 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.

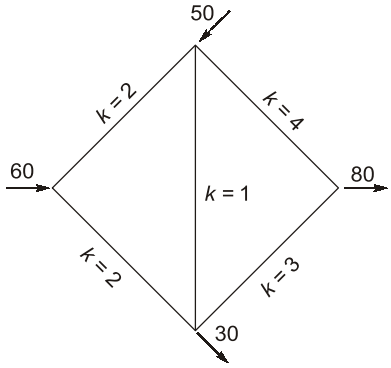
(ii) The flow entering a junction must be equal to the flow leaving the same junction.

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

Steps

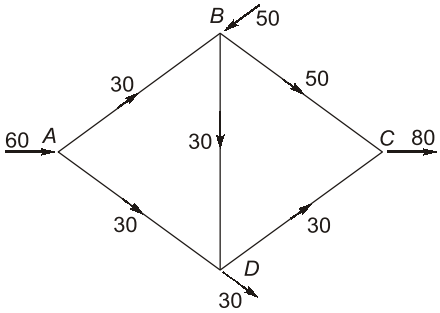
- Assume flow in each pipe satisfying continuity equation.
- Take clockwise flow as positive, anticlockwise flow as negative.
- Modification in discharge $\Delta Q = \dfrac{(-)\sum rQ^n}{\sum\left|rnQ^{n-1}\right|} - \dfrac{\sum h_L}{n\sum\left|h_L/Q\right|}$
- ΔQ is added algebraically
- The direction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

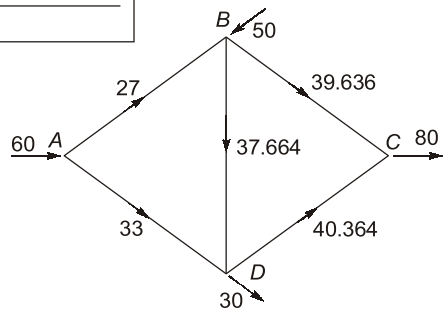
Pipe	Assumed flow Q	k	$h_L=kQ^2$	$[h_L/Q]$	Corrected flow
AB	30	2	1800	60	27
BD	30	1	900	30	27 + 10.364 = 37.364
DA	–30	2	–1800	60	–33
			Σ = 900	Σ = 150	

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

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	

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



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.

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.

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.

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.

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.

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 Service Connection

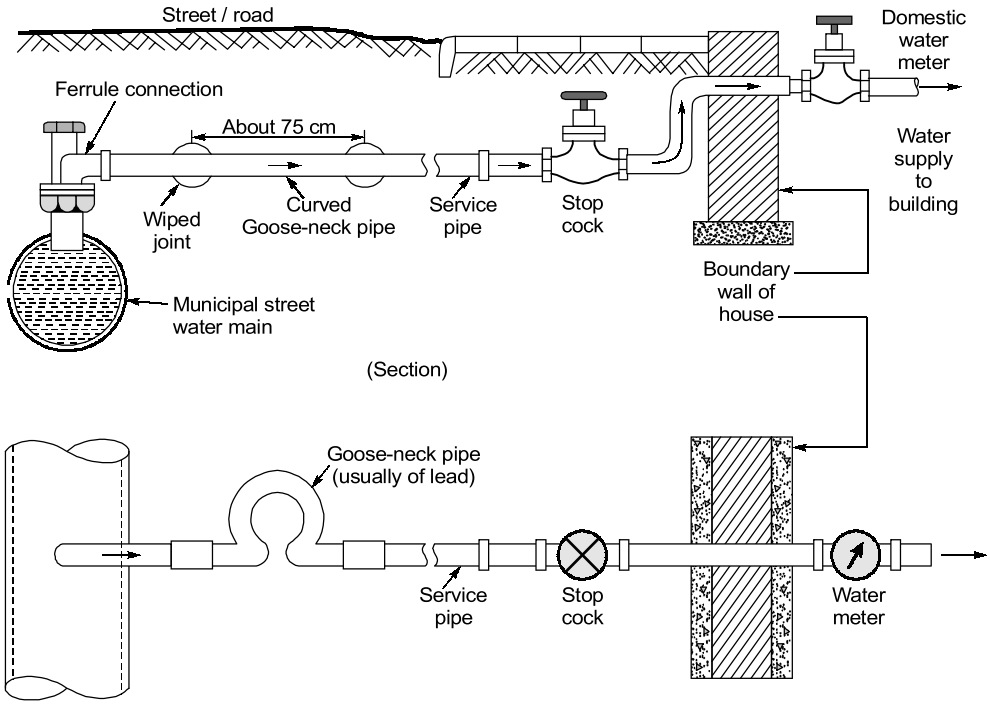


Fig. 5.5 Service Connection

Service connection includes following components.

1. **Brass or bronze Ferrule or made of gun metal:** Its size varies from 10 to 50 mm in diameter.
2. **Goose neck :** Small sized curved pipe made of a flexible material (Usually made up of lead) and is about 75 cm in length. This forms flexible connection between water main and service pipe.
3. **Service pipe :** It is a galvanized iron pipe of size less than 50 mm dia.
   (Generally 12 mm to 50 mm)
4. **Stop cock :** Stop cock is provided before the water enters the water meter in the house to close down the supply, for repairs of the plumbing system.
5. **Water meter :** Measures and records the quantity of water consumed in the house. The domestic water meter (displacement type) is fitted in to service pipe with 'unions'.
6. **Water taps and Bib cocks :** Valves provided at the end of service pipes for withdrawing water at the consumers houses. The commonly used water tap is bib cock. Bibcock may be of rotating type or push type.

Example - 5.4 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)

5.15 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.

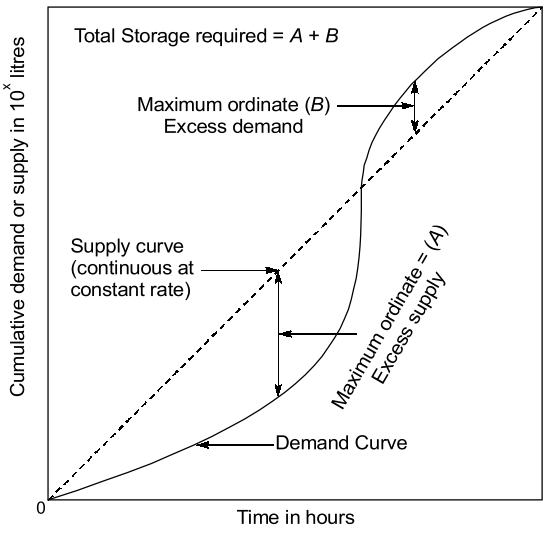


Fig. 5.6 Continuous Supply

- 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.

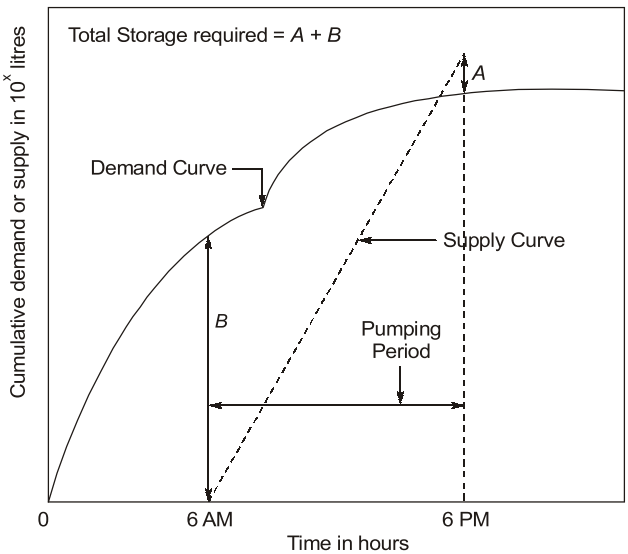


Fig. 5.7 Limited Hour Supply

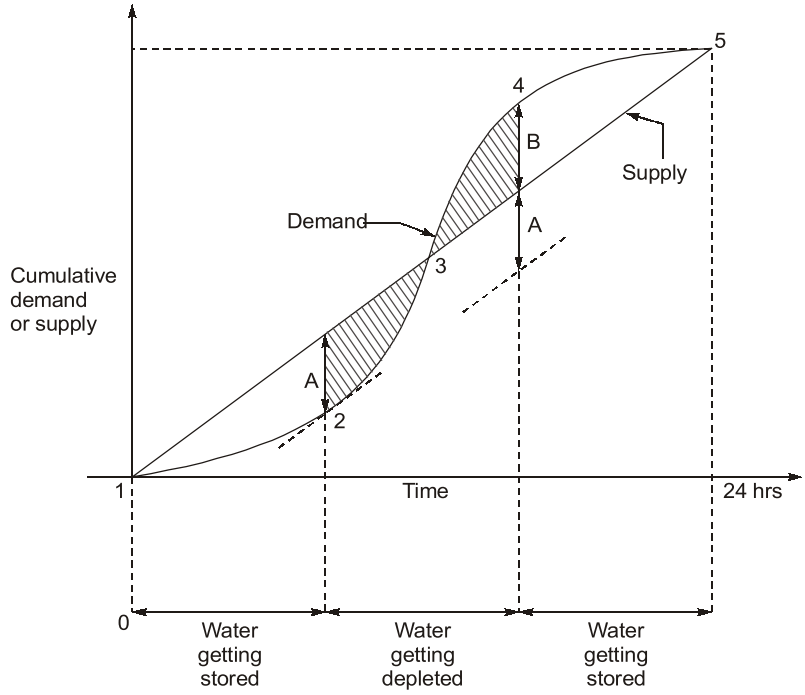


Fig. 5.8 Limited Hour Supply

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 - 5.5 The purpose of providing a balancing reservoir in a water supply distribution system is to

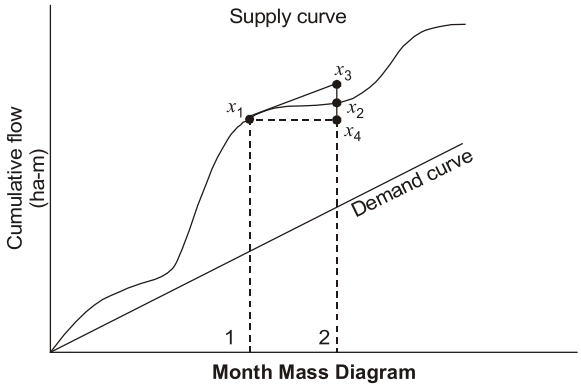
(a) equalize pressures in the distribution system
(b) stores adequate quantity of water to meet requirements in case of breakdown of inflow
(c) store adequate fire fighting reserve
(d) take care of fluctuations in the rate of consumption

Ans. (d)

Example - 5.6 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 - 5.7 Calculate the storage required to supply the demand shown in the 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

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

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

Time in hour	Demand in M*l*	Cum demand in M*l*	Supply in M*l*	Cum Supply in M*l*	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.

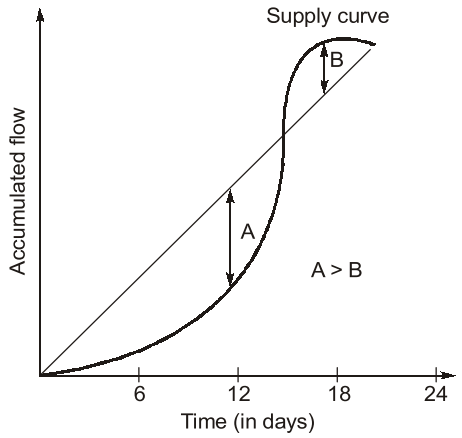
Student's Assignment

Q.1 The suitable layout for a water supply distribution system, for an irregulary grown town is
(a) dead end system (b) grid iron system
(c) ring system (d) radial system

Q.2 The suitable layout for a water supply distribution system, for a city of roads of rectangular pattern is
(a) dead end system
(b) grid iron system
(c) ring system
(d) radial system

Q.3 The method, which is most widely used for analysing and designing the pipes of all types of complex water distribution networks is
(a) equivalent pipe method
(b) Hardy cross method
(c) circle method
(d) All of the above

Q.4 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.5 Consider the following units associated in water supply system:
1. Pumping of raw water
2. Intake works
3. Treatment works
4. Distribution system

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.6 A sudden change in the slope of the hydraulic gradient line drawn for a straight sections of the water pipe line indicates.
(a) Change in ground slope
(b) Presence of water hammer
(c) accumulation of sediments
(d) Leakage in pipe line

Q.7 Which one of the following is purpose of providing a surge tank in a pipeline carrying water?
(a) To store water
(b) To increase pressure throughout pipeline
(c) To store overflowing water
(d) To protect pipeline against water hammer

Q.8 An inverted siphon is a
(a) device for distribution septic tank effluent to a soil absorption system.
(b) device for preventing overflow from elevated water storage tank.
(c) device for preventing crown corrosion of sewer.
(d) Sections of sewer, dropped below hydraulic grade line in order to avoid an obstacle.

Q.9 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.10 For one storey building in town, the minimum residual pressure at ferrule point for direct supply should be
(a) 3 m (b) 5 m
(c) 7 m (d) 10 m

Q.11 Why are gate valves provided in distribution system.
(a) To minimize flow pressure in network.
(b) to maximize ways of distribution system.
(c) To control flow in pipe network.
(d) To identify loss through illegal connections.

Q.12 Match **List-I** (Layout) with **List-II** (Suitable For) and select the correct answer using the code 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.13 The design technique, adopted in design of large water supply networks, as an aid to simplify and separate the smaller loops is
(a) Hardy cross method
(b) Circle method
(c) electrical analyser method
(d) equivalent pipe method

Q.14 The water meter, which is installed on individual house connections, on municipal suppliers is
(a) a velocity meter
(b) an inferential meter
(c) a displacement meter
(d) None of these

Q.15 The water-tap of your house is known as
(a) sluice tap
(b) stop cock
(c) bib cock
(d) ferrule

ANSWER KEY // STUDENT'S ASSIGNMENTS

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

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENTS

7. (d)

Surge tanks are provided at the end of the line where water hammer is created by rapid closing.

9. (d)

Demand = 6.10 ML/hr
Supply = 1.5 m^3/sec

$$= \frac{1.5 \times 1000}{\left(\frac{1}{3600}\right)} \text{ ML/hr}$$

= 5.4 ML/hr

∴ Water requried to be augmented from a storeage reservoir is

= 6.1 – 5.4 = 0.7 ML/hr

10. (c)

Number of storey	Minimum residual pressure
1	7 m
2	12 m
3	17 m