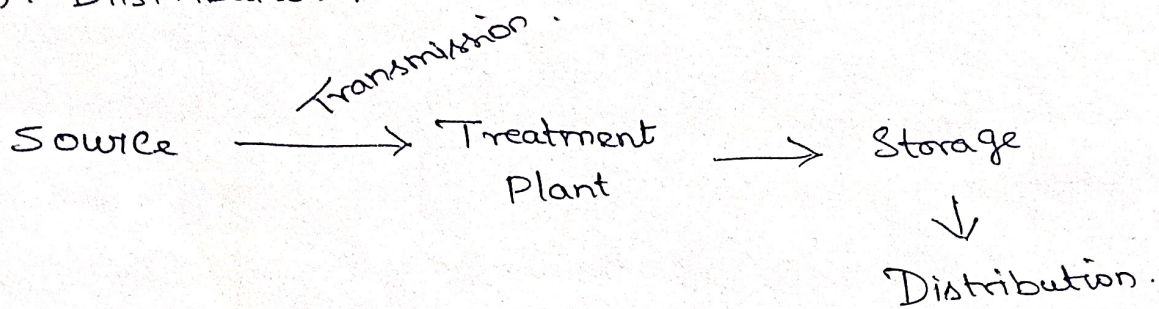


## Unit - 1

### Source of Water.

#### Public Water Supply System:-

- Components :-
1. Collection of Water from Source.
  2. Transmission Work,
  3. Treatment,
  4. Storage.
  5. Distribution.



#### Planning:

In Planning Water Supply system, It is essential to find source of water. Sometimes source may be available nearby, and sometimes it may be far away.

It may be underground well, lake, (or) river (or) stream. It is necessary to seek out all the possible sources and evaluate cost, quantity and quality.

Suitable system to be designed for collecting, transporting, and treating this water.

The treated water finally distributed to the residents.

Objectives :-  $\frac{2}{3}$  of human body constituted of water.

⇒ To Provide Potable water to the various Community in accordance with their demands.

⇒ To Supply safe and wholesome water

⇒ Help maintaining better sanitation and beautification of surroundings, there by reducing environmental pollution.

⇒ Help in Industrialisation and modernisation of the society, consequently reducing unemployment and ensuring better standards.

Wholesome water :- The water is safe and Potent for drinking to human health.

Which will neither contain any chemicals or impurities in excess.

Wholesome water will always be safe.

Kolkata - 10 hours / day. (water supply system installed - 1870)

Delhi - 6 hours / day. &

## Design Period:-

The future period for which a provision is made in the water supply scheme is known as the design period.

A water supply scheme includes huge and costly structure which cannot be replaced (or) increased in their capacities easily and conveniently. In order to avoid these future complications components of water supply schemes are purposely designed for large, so as to satisfy the community needs for a reasonable # of years.

This future period or the number of years for which a provision is made in designing the capacities of the various components of the water supply scheme is known as design period.

The design period should neither too long nor should it be too short.

The design period can't exceed the useful life of the components.

## Factors governing the Design Period:-

⇒ Useful life of components and chance of their becoming old and obsolete.

⇒ Ease and difficulty, faced in expansion. more difficult expansion mean choosing a higher value of the design period.

⇒ Amount and availability of additional investment likely to be incurred for additional provision. Ex if the funds are not available, one has to keep a smaller design period.

⇒ The rate of interest for the additional money (or) borrowing invested. Ex Interest is small, higher value of the design period economically justified.

⇒ Anticipated rate of growth population, including possible shifts in communities, industries and commercially establishment. Ex rate of ↑ of population is less, a higher design period may be chosen.

## Design Period value:-

storage dam	- 50 yr	Treatment units	- 15 yrs.
Intake work	- 30 yr.	Pipe connection in treatment units	- 30 yr
Pump work.		Raw & clear water conveying	- 30 yr
Pump house	- 30 yr	Distribution system	- 30 yr.
Electric motor Pump	- 15 yr.		

# Population Forecasting.

## Population Data:-

The Present Population of a town or city can be determined by conducting census. The government of all country generally carries surveys at interval of 10 years.

Sometimes smaller period surveys are conducted by state government by local bodies.

These are first of all, collected by the planners of water supply scheme. is then used for predicting the future population of the city, at the end of the design period.

The Present Population, if needed, is generally determined by extending the line of the last two preceding.

## Population Growth:-

There are three main factors responsible for changes in Population.

(i) Births, (ii) Deaths.

(iii) migration.

Birth rate :- may decrease due to excessive family planning, legal abortion.

Death rate :- may decrease with medical facility, infant mortality, control of infection and diseases.

migration :- depend on industrialisation, commercialisation of particular cities.

People generally migrate from village to cities.

Population data and growth generally depend on these three factors mainly.

Some other factors like wars, natural disasters, affect the population rate.

Ideal Population Curve :-

AB - early growth, at an increase rate called geometric or log growth.

$$\frac{dP}{dt} \propto P.$$

DE - late growth, at a decreasing rate first order curve, saturation value.

$$\frac{dP}{dt} \propto (P_s - P).$$



## Population forecasting Methods :-

Various methods are adopted for estimating future Population by engineers.

Some of these methods are used 'when the design Period is small', and 'Some are used 'when the design Period is large', and some for Particular case or Particular cities.

selection is left to the discretion and intelligence of the designer.

None of these method is exact. they all are based on the laws of Probability. Only approximate estimates for the Possible future Population can be made.

- ⇒ Arithmetic Increase Method.
- ⇒ Geometric Increase Method.
- ⇒ Incremental Increase Method.
- ⇒ Decreasing Rate of growth.
- ⇒ Simple Graphical Method.
- ⇒ Comparative Graphical Method.
- ⇒ Master Plan Method.
- ⇒ Ratio Method.
- ⇒ Logistic Curve Method.

## Arithmetic Increase Method:-

The rate of change of Population with time is constant rate.

$$\frac{dP}{dt} = k.$$

$$P_n = P_0 + n\bar{x}.$$

$P_n \Rightarrow$  forecasted Population after  $n$  decades.  
from Present.

$P_0 \Rightarrow$  Present Population.

$\bar{x} \Rightarrow$  Arithmetic mean (or) Avg of Population  
increases in the known decades.

$n \Rightarrow$  No. of decades b/w now and future

'Population increased' at a 'constant rate'.

The Population of 5 decades from 1930 to 1970 are given below. Find out the Population after 1, 2, 3 decades beyond the last known, using arithmetic increase Method.

Year	⇒ 1930	1940	1950	1960	1970
Population	⇒ 25,000	28,000	34,000	42,000	47,000.

Sol

Year	Population	Increase in Population (x)
1930	25000	-
1940	28,000	3000
1950	34,000	6,000
1960	42,000	8,000
1970	47,000	5,000

$$\bar{x} = \frac{\sum x}{4}$$

$$= \frac{3,000 + 6,000 + 8,000 + 5,000}{4} = \frac{22,000}{4}$$

$$\bar{x} = 5,500$$

$$P_n = P_0 + (n \cdot \bar{x})$$

$$P_{1980} = 47,000 + (1 \times 5,500)$$

$$= 52,500 \text{ t}$$

$$P_{1990} = 47,000 + (2 \times 5,500)$$

$$= 58,000 \text{ t}$$

$$P_{2000} = 47,000 + (3 \times 5,500) = 63,500 \text{ t}$$

## Geometric Increase Method:-

Percentage growth rate is constant.

The increase is compounded over the existing population every year (decade), therefore also known as uniform increase method.

Difference b/w Arithmetic and geometric Method of forecasting future population is:

In  $\Rightarrow$  The arithmetic method no compounding is done. - Geometric compounding is done every decade.

$\Rightarrow$  The computation in two methods are simple and compound interest computation.

"rate of increase per annum -  $r$ "

$$P_n = P_0 \left(1 + \frac{r}{100}\right)^n$$

$r$  = Assumed growth rate (%)

$P_n$  = future population after 'n' decade.

$$r = \frac{\text{increase in Population}}{\text{original Population}} \times 100.$$

The average may again be either arithmetic.

$$= \frac{r_1 + r_2 + r_3 \dots + r_t}{t}$$

or the geometric average

$$= \sqrt[t]{r_1 * r_2 * \dots * r_t}$$

Ex.

The Population of 5 decades from 1930 to 1970 are given below. Find out the Population after 1, 2, 3 decades after beyond the <sup>last</sup> known decade, using geometric increase method.

Sol:

Year	Population	Increase in Population	% increase in Population (n)
1930	25,000		
1940	28,000	3000	$\frac{3000}{25000} = 12\%$
1950	34,000	6000	$\frac{6000}{28000} \times 100 = 21.4\%$
1960	42,000	8,000	$\frac{8000}{34000} \times 100 = 23.5\%$
1970	47,000	5,000	$\frac{5000}{42000} \times 100 = 11.9\%$

Geometric mean of the growth rates.

$$r = \sqrt[4]{12 \times 21.4 \times 23.5 \times 11.9}$$

$$= 16.37\%$$

in arithmetic average.

$$r = \frac{12 + 21.4 + 23.5 + 11.9}{4} = 17.2\%$$

$$P_n = P_0 \left(1 + \frac{r}{100}\right)^n$$

$$P_{1980} = 471000 \left(1 + \frac{16.37}{100}\right)^1$$
$$= 54,694.$$

$$P_{1990} = 47000 \left(1 + \frac{16.37}{100}\right)^2$$
$$= 63,647$$

$$P_{2000} = 47000 \left(1 + \frac{16.37}{100}\right)^3$$
$$= 74,066.$$

## Incremental Increase Method:-

In this method, the per decade growth rate is not assumed to be constant as in the arithmetic (or) geometric Progression.

Progressively Increase (or) decrease depend upon whether the average of Incremental increases in the Past data is +ve (or) -ve.

The Population for a future decade is worked out by adding mean arithmetic increase ( $\bar{x}$ ) to the last known Population in the arithmetic inc method, and to this is added the avg of the Inc. increases ( $\bar{y}$ ) once for the first decade, twice for the 2<sup>nd</sup> decade and so on.

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \bar{y}$$

$P_n$  = Population after  $n$  decades.

$\bar{x}$  = Average increase of Population of known decade.

$\bar{y}$  = Average Incremental Increase of Population of known decade.

This method will give end result somewhere between the "arithmetic and geometric increase method. satisfactory results.

The 'geometric Increase' method gives highest values of forecasted Population. It may be suitable for 'new younger cities' expanding at faster rate.

Incremental Increase method is considered to be best for any city, whether old (or) new.

Problem On Incremental Increase Method:-

Estimate the Population of the locality in 1980.

Census Year	Population	Increase in Popul	In. Inc. in Popul.
1880	8000	-	-
1890	12000	4000	+1000
1900	171000	5000	+1500
1910	221500	5500	1000
1920	291000	6500	2000
1930	371500	8500	1000
1940	471000	9500	500
1950	571000	10,000	-500
1960	661500	9,500	-

$$\bar{x} = \frac{4000 + 5000 + 5500 + 6500 + 8500 + 9500 + 10,000 + 9500}{8}$$

$$\bar{x} = 7313 \text{ -}$$

$$\bar{y} = \frac{1000 + 500 + 1000 + 2000 + 1000 + 500 - 500}{7}$$

$$= \frac{5500}{7}$$

$$\boxed{\bar{y} = 786} \text{ t}$$

$$P_{1980} = P_0 + n\bar{x} + n \frac{(n+1)}{2} \bar{y}$$

$$P_{1980} = 66500 + 2 \times 7313 + \frac{2(3)}{2} (786)$$

$$= 66500 + 2 \times 7313 + 3 \times 786$$

$$P_{1980} = 83,484 \text{ t}$$

Population after 2 decades will

be  $P_{1980} = 83,484 \text{ t}$

The Population of 5 decades given below.  
 Find out the Population after 1, 2, 3 decade beyond  
 the last known Population, using Incremental  
 Increase method.

Sol:-

Year	Population	Increase in Population ( $x$ )	Incremental Increase ( $y$ )
1930	25000	—	—
1940	28000	3000	—
1950	34000	6000	3000
1960	42000	8000	2000
1970	47000	5000	- 3000

$$\bar{x} = \frac{3000 + 6000 + 8000 + 5000}{4} = 5500$$

$$\bar{y} = \frac{3000 + 2000 - 3000}{3} = 667$$

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \bar{y}$$

$$P_{1980} = 47000 + 5500 + 667$$

$$= 53,167$$

$$P_{1990} = 47,000 + 11,000 + 3 \times 667$$

$$= 60,001$$

$$P_{2000} = 47,000 + 16,500 + 6 \times 667$$

$$= 67,502$$

## Decreasing rate of growth Method :-

The rate of Increase in Population goes on reducing, as the cities reach towards Saturation, .

This method used many time where decrease in % of increase and gives quite reasonable results.

In this method avg decrease in % increase is worked out and is subtracted from the latest % inc for each successive decade

"The rate of growth shows a downward trend".

$$P_n = P_0 + \frac{r_1 - i}{100} \times P_0$$

$i =$  <sup>Avg of</sup> decrease in the % increase.

### Example

Year	Population (P)	Increase in Population	% Increase in Population	Decrease in % inc
1930	25000	-		
1940	28000	3000	12%	-9.40
1950	34000	6000	21.4%	-2.1%
1960	42000	8000	23.5%	+11.9%
1970	47000	5000	<u>11.9%</u>	

$$= -11.5 + 11.9$$

$$= 0.1\%$$

$$\text{Average Per decade} = \frac{0.1}{3} = 0.03\%$$

$$\begin{aligned} P_{1980} &= 47000 + \frac{11.9 - 0.03}{100} \times 47000 \\ &= 471000 + 5570 \\ &= 52570 \end{aligned}$$

$$\begin{aligned} P_{1990} &= 52570 + \frac{11.87 - 0.03}{100} \times 471000 \\ &= 52570 + 6230 \\ &= 58800 \end{aligned}$$

$$\begin{aligned} P_{2000} &= 58800 + \frac{11.84 - 0.03}{100} \times 47000 \\ &= 65750 \end{aligned}$$

### Simple Graphical Method :-

In this method a graph is plotted from the available data, between time and Population. The curve is then smoothly extended upto the desired year. It gives very approximate results.

The extension of the curve is done by the intelligence of the designer.

### Comparative Graphical Method :-

In this method, the cities having conditions and characteristics similar to the city, whose future Population is to be estimated are, first of all, selected. It is then assumed that the city consideration will develop, as the selected similar cities have developed in the past.

This method has a logical background

~~and if~~

### Master Plan Method :-

## Water Demand:-

While Planning a water supply scheme, it is necessary to find out not only the total yearly water demand but also to assess the required averages rates of flow and the variations in these rates.

## Per Capita Demand:-

Annual average rate of water required in Litre Per day Per Person, called Per capita demand (q).

(1) Domestic water demand.

(2) Industrial water demand.

(3) Institution and commercial water demand.

(4) Demand for Public use.

(5) Fire demand.

(6) Water required to compensate losses in

wastes and theft.

## Domestic Demand:-

Use	Per capita with full flush	without full flush
Drinking .	5	5
Cooking	5	5
Bathing	75	55
Washing clothes	25	20
Washing utensils	15	10
house cleaning.	15	10
Gardening	15	-
Water closets.	45	30
	200 l/hd	135 l/hd

The total domestic water demand shall be equal to the total design population multiplied by per capita domestic consumption.

Water demand :-

Types	Water Required. (l/h/d).
Domestic	200 l/d
Industrial water demand	50 l/d.
Institutional and Commercial demand	20 l/d.
Demand for Domestic Use for Public	10 l/d.
Fire demand	(1 l/d if necessary)
Compensate losses and theft	55 l/d
	<hr/> 335 l/h/d).

Fire demand :-

The amount of water required to stop the fire break out is called fire demand.

Kuichling's formula:

$$Q = 3182\sqrt{P}$$

P - Population in thousands.

2) Freeman formula.

$$Q = 1136 \left[ \frac{P}{10} + 10 \right]$$

3) National Board of Fire under Writers Formula:-

For congested high valued city:-

$$Q = 4637 \sqrt{P} [1 - 0.01 \sqrt{P}]$$

4) Buston's formula:-

$$Q = 5663 \sqrt{P}$$

Factors affecting Per capita demand:-

- 1) Size of the city.
- 2) Climate conditions.
- 3) Types of Gentry and habits of People.
- 4) Industrial and commercial activity.
- 5) Quality of water supplies.
- 6) Pressure in the distribution system.
- 7) System of supplies.
- 8) Cost of water.

Factors affecting losses and wastes:-

- 1) Water tight joint
- 2) Pressure in the distribution system.
- 3) System of supply.
- 4) Metering.
- 5) Unauthorised connections.

## Selection of source:-

- (1) The Quantity of available water.
- (2) The quality of available water.
- (3) Distance of the source of supply.
- (4) General topography of the intervening Area.
- (5) Elevation of the source of supply.

## Surface Sources of water supplies:-

The water flows over the surface of the earth, and thus directly available on water supplies.

- ⇒ Natural Ponds and lakes.
- ⇒ Streams and river.
- ⇒ Impounding reservoir.

## Natural Ponds and Lakes:-

A natural large sized depression formed within the surface of the earth, when gets filled up with water is known as Pond or Lake.

Pond - If the size of depression small  
Lake - If the size of depression large.

Quality: of water in a lake is generally good, no need much Purification. Larger and older lakes provide much Pure water than the smaller and newer one.

Self Purification of water due to sedimentation of suspended matter, bleaching of color, removal of bacteria, etc. makes lake's water Purer and better.

In still water of lakes and ponds, the algae, weed and vegetable growth take place freely imparting bad smells.

Quantity: Quantity of water available in the lakes and ponds are smaller, and thus so it is not considered as Principal source. If there is no other source, larger lakes may become Principal source of supply.

Streams and rivers:-

Small streams feed their water to the lakes or river. It is not suitable for water supply scheme, because the quantity of water available in them is very small.

They are useful sources only for small villages, especially in hilly areas.

Larger and Perennial river & streams may be used as sources of water.

Rivers are the most important sources of water supply scheme. Perennial sources rivers are those in which the water is available throughout the year.

The quantity of water obtained from river is generally not reliable. It contains large amount of silt, sand and a lot of suspended matter.

The disposal of the treated and untreated sewage into the rivers. The river water must be properly analysed and well treated before supplying to the public.

Storage reservoir :-

Pool or artificial lake formed on the upstream side of the dam is known as storage reservoir.

The quality of this reservoir water is not much different from that of a natural lake.

The water stored in the reservoir can be used easily not only for water supplies, but also for other purposes.

## Sub-Surface / Under ground Sources:-

The water, which gets stored in the ground water reservoir through infiltration, is known as under ground water.

This water is generally pure, because it undergoes natural filtration during the percolation through the soil pores.

It contains less contaminants by bacteria. They are rich in dissolved salts, minerals, gases.

The ground water is largely tapped in our country for water supplies and there is a scope for its development in future.

## Characteristics of Water :-

### 1) Physical characteristics :-

- 1) Turbidity - 5 - 10 PPM.
- 2) Colour - 10 - 20
- 3) Taste - No taste
- 4) Odour - 1 - 3.
- 5) Temperature -  $10^{\circ}\text{C}$  ; not exceed  $25^{\circ}\text{C}$ .
- 6) SP. Conductivity of water - 0.54 - 0.96.  
( $25^{\circ}\text{C}$  - TDS).

### 2) Chemical Characteristics :-

- Total Solids, Suspended solids - 500 PPM  
(not exceed 1000 PPM).
- pH - 6.6 - 8.5.
- Hardness of water - 75 - 115 PPM.
- chloride content - not exceed 250 PPM.
- Free ammonia - 0.15 mg/l.
- organic nitrogen (Kjeldahl nitrogen) - 0.3 mg/l.
- Nitrites - Nil.
- Nitrates - 45 mg/l  
(methyoglobinemia)

## 2. Conveyance From The Source.

### Intake Structures :

constructed at entrance of the conduit and thereby helping in protecting the conduit from being damaged.

The basic function of the intake structure is to help in safely withdrawing water from the source over a predetermined range of pool levels and then to discharge this water into the withdrawal conduit through which it flows up to the water treatment plant.

### Factors governing location of an Intake:-

- ⇒ site should be near the treatment plant.
- ⇒ intake must be located upstream zone of source, so that ~~reduce~~ load on treatment plant.
- ⇒ The intake should never be located near the navigation channels, to avoid the pollutants due to discharge of refuse and waste from ships.
- ⇒ The site should be such as to permit greater withdrawal of water, if required at a future date.
- ⇒ The Intake site should remain easily accessible during floods.

## Types of Intakes.

⇒ Simple submerged

⇒ Intake towers.

1) Wet intake.

2) Dry intake.

⇒ River intake

⇒ Canal intake.

⇒ Intake for sluice way. of Dams.

## Simple Submerged intake:-

The intake opening is generally covered by screen, to prevent entry of debris into the withdrawal conduit

In case of lake, where silt tends to settle down, intake opening is generally kept at about 2-2.5m. above the bottom of lake to avoid entry of large amount of silt.

Such intake structure should be placed in streams or lake at a place where they may not be buried under sediment.

It is a cheap and generally does not obstruct navigation.

widely used for small water supply projects.

These intakes are not used for bigger projects on rivers and streams. not accessible for cleaning, repairing, etc.

## Intake Towers :-

⇒ Wet intake towers.

⇒ Dry intake towers.

### Wet intake towers :-

It may consist of circular shell filled with water upto the reservoir level.

The withdrawal may be taken directly to the treatment plant in case no lift is required. or to the sump well in the case a low lift is req.

Withdrawal conduit may lie over the bed or may be the tunnel below the river bed.

Openings are made into the outer concrete shell, as well as into the inside shaft.

Gates are usually placed on the shaft, so as to control the flow of water into the shaft and the withdrawal conduit.

The water coming out of the withdrawal conduit may be taken to Pump house for lift, if the city's water treatment plant is located at higher elevation.

## Dry intake towers :-

The essential difference between a dry intake and wet intake is that, whereas in a wet intake, the water enters from the entry port into the tower and then it enters into the conduit through separate gate controlled opening.

In a dry intake tower, the water is drawn into the withdrawal conduit through the gated entry ports.

Dry Intake towers have no water inside the tower, if the gates are closed.

## River intake structure :-

- (i) Twin well intake
- (ii) single well intake.

## Twin well - type of River intake structures :-

River Intake structure consist of :-

- i) Inlet well
- ii) Inlet Pipe.
- iii) Jack well.

Inlet well :- It is circular, located in the river bed, it always remain surrounded with water, even during low flow stage.

The Well is built in masonry is raised above the river H.F.L. and covered at the top by wooden sleepers.

Sometimes, screened openings are provided in the full height of inlet well and are controlled by gates, as to enable the water to enter the inlet well from any desired level, depending upon the river level.

The inlet well is connected to Jack well, which is constructed on the river bank, by a R.C.C intake pipe.

Intake Pipe :-

connecting intake well with the Jack well, is usually non-pressure type and is laid with a gentle slope 1 in 200 towards the Jack well.

The diameter of pipe depend upon its discharge capacity, which should be equal to the Pumped discharge from the Jackwell. velocity 1.2 m/s, dia should not less than 45cm.

Smaller pipes may get choked and difficult to clean.

Jack well : water entering from the intake pipe is lifted by pumps and is fed into rising main through delivery pipe.

It should be located as close to river as possible. bearing capacity of Jack well should not be less than  $450 \text{ kN/m}^2$ .

Suitable high-head turbine or centrifugal pump may be used to lift water from Jack well.  
dia of Jack well - 4-5 m

Single well - Type of river Intake :-

In alluvial rivers, water is usually provided up by construction of weir across the river. From the upstream side of such a weir, a channel may sometimes be taken off, as in a usually diversion head works scheme.

The water entering this off-taken canal may then be collected and lifted for supply to the city treatment plant located at a higher elevation.

This arrangement will eliminate the construction of an inlet well and inlet pipe as are required in the twin well type of river intake.

## Canal Intake :-

In case of canals, the intake well is generally located in the bank of the canal, and water enters the chamber through an inlet pipe covered with a fine screen.

The flow velocity in the canal increases due to reduction in water way, and hence pitching is generally provided on to the upstream as well as down stream portion of the canal near the intake.

The flow velocity through the outlet conduit is generally kept at about 1.5 m/s. and this helps determining the area and dia of withdrawal conduit.

The entry of the water in the intake well takes through coarse screen, the area of coarse screen is designed by limiting velocity to as low as 0.15 m/s.

The flow velocity through the bell mouth intake is limited to 0.3 m/s.

The head loss in the intake conduit, <sup>to treatment works</sup> is determined by using 'Hazen Williams' formula, eq

$$V = 0.85 C_H R^{0.63} S^{0.54}$$

R - hydraulic mean depth (circular -  $d/4$ ).

## Conduits :-

Water supply schemes consist of collecting water from the source, carrying it to the treatment plant in the city and finally distributing the treated water among the consumers by means of conduits.

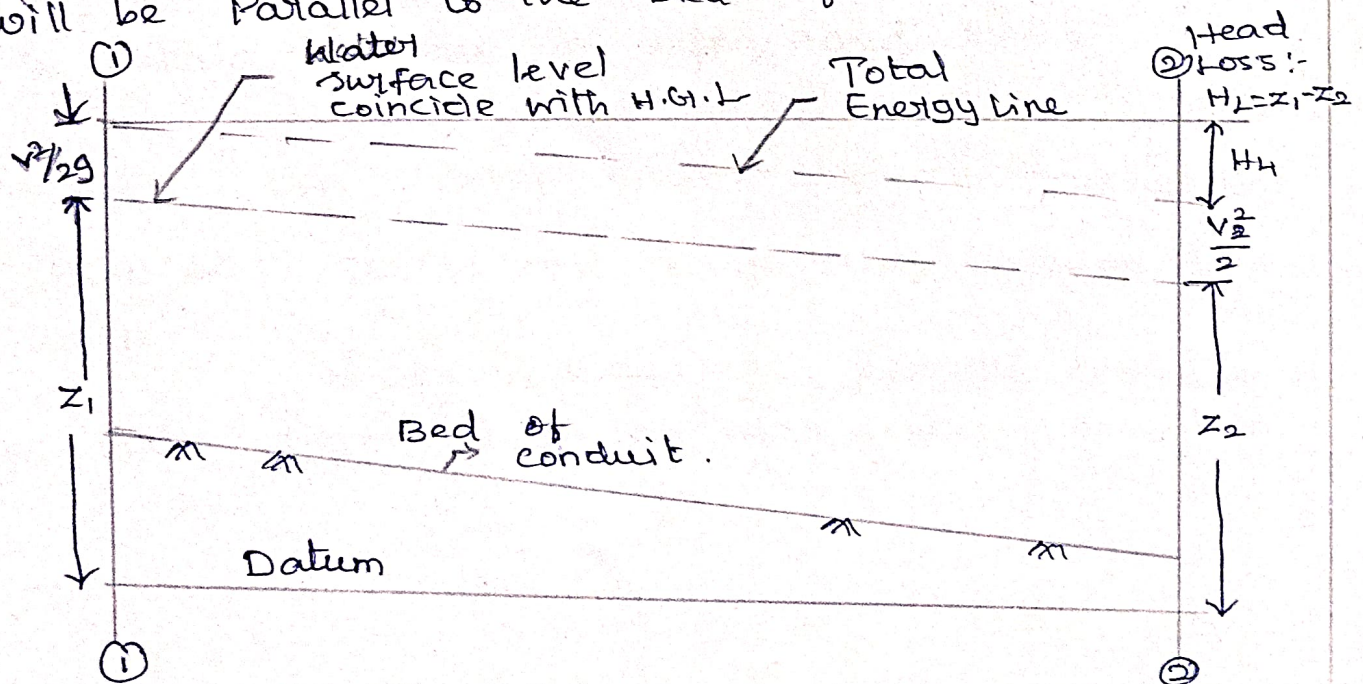
## Types

- 1) Gravity Conduits.
- 2) Pressure Conduits.

## Gravity Conduits :-

in which water flows under the mere action of gravity.

In such a conduit hydraulic gradient line will co-incide with the water surface and will be parallel to the bed of the conduit.



This is so, because in such a flow, the water is all along at atm. Pressure, and thus there is no Pressure term in Bernoulli's eqn.

Since the bed of such a conduit has to follow the gradual slope of the gradient line.

The gravity or grad conduit will, therefore, have to follow this gradual slope and does not follow the natural slope.

These conduit cannot, therefore, go up and down hills and valleys as desired by the existing topography of the area.

Alternatively, they may be carried along zig-zag path like roads, Highways, etc.,

Gravity conduits can be in the form of canals, flumes, or ~~a deep~~ aqueducts.

Canals: open channel which are constructed by cutting high ground and constructing bank on lower grounds.

However, they are generally not used for water supplies but are often used for irrigation.

Flumes: Open channels supported above the ground over trestles, etc., are called flumes.

They are used to convey water across valleys and minor depressions or over drains and other obstruction in their path.

They are made of masonry, R.C.C., metal and are usually circular and rectangular.

Aqueducts:- Closed rectangular or circular or horse shoe section. built of masonry.

They wind their ways through land -scape, with gradual slopes, like roads, railways and highways.

Water does not flow under pressure, as they are not allowed to run full.  $\frac{1}{2}$  or  $\frac{3}{4}$  flow.

Circular section provides the maximum hydraulic mean depth  $R = A/P$ , and is therefore the most efficient.

## Pressure Conduit:-

Which are closed conduits and as such as no air can enter into them, the water flows under pressure above the atmospheric pressure.

The HGL for such conduit can be obtained by joining the water surface elevation in the Piezometers installed in the conduit at various place.

The Pressure Pipe follow the natural available ground surface and freely go up and down hills or can dip beneath valleys, mountains sometimes even rising.

Very less chances of getting pollution.

The Pressure pipes are, therefore invariably and universally used for water supplies where as gravity conduits are generally adopted for carrying sewage and drains.

## Hydraulics of flow :-

If the pipes goes much below the hydraulic gradient line, naturally the Pressure developed.

Size and shape of the supply pipe must be determined by hydraulic, structural and economical consideration.

The velocities should also be non-silting and non-scouring. The flow velocities are normally kept between 0.9 to 1.5 m/s.

The head loss caused by Pipe friction can be found by using formulae:-

i) Darcy Weisbach formula:-

$$H_L = \frac{f' L}{d} \times \frac{V^2}{2g}$$

ii) Manning's formula:-

$$H_L = \frac{n^2 \cdot V^2 \cdot L}{R^{4/3}}$$

iii) Hazen William's formula:-

$$V = 0.85 C_H R^{0.63} S^{0.54}$$

iv) Modified hazen William's formula.

$$V = \frac{3.83 C_R (d^{0.6575} (4.5)^{0.5525})}{S}$$

$$(or) V = 143.53 C_R \cdot R^{0.6575} S^{0.5525} V^{0.105}$$

Water Supply works :-

mainly consist of Pipes Lines. The connections with water mains should be enumerated, stating size and length of pipe from the water main up to the property together with the charges of water and local authority.

The lines are estimated on running metre. (or ft) basis for different diameter for the complete work with fittings supplying and fixing in position.

Including digging, laying, refilling, jointing, etc. Fittings as stop cock, Bibcock, ferrule, etc. are estimated numberwise supplying G.I. overhead tank of various capacities, fitted with ball cock, are estimated numberwise supplying and fixing in position for complete work.

Water main Pipes may be Galvanised Iron (GI), cast Iron (CI), steel, Hume steel, R.C.C. etc. For small diameter usually GI Pipes are used for diameter up to 60cm C.I Pipes are used.

Valves, stop valves, air valves, etc. are provided as required, which are estimated number wise.

## Testing of the Pipe line :-

⇒ The Pipe line is tested from section to section, Thus at a time only one Particular section lying b/w 2 sluice valves is taken up for testing.

⇒ The downstream sluice is closed, and water is admitted into pipe through upstream sluice. The air valve will be operated during filling up of the pipe.

⇒ The upstream valve, through which the water is admitted, is closed, so as to completely isolate the pipe section from the rest of pipe.

⇒ The Pressure gauge are then fitted along the length of pipe section at suitable interval on the crown, through holes left for this purpose.

⇒ The Pressure in the pipe line is now raised by means of a small hand force pump or a hydraulic pressure pump, till test pressure (measured on the pressure gauge) is nearly 25-50% above the highest working pressure.

⇒ The pipe and the joints are then visualized for water tightness

field test pressure is less than  $\frac{2}{3}$ rd the work test pressure.

## Laying of water Supply Pipes

⇒ Pipes are used for conveying water from the source to the city, and also for distributing them among the consumers.

⇒ For bringing water from the source to the city, one or two lines of same dia. generally laid.

⇒ distributing water, generally varying size having many connection and branches.

⇒ Pipes laid either above or below the ground. Pipe bringing water from the source is generally laid above the ground. distributing pipes in localities laid below the ground.

⇒ Pipe layed above the ground directly over the compacted soil formation or cement concrete support at 6-12 meter apart. to avoid future settlement.

⇒ Pipe laid below the ground, laid in trenches excavated upto required depth.

⇒ TOP of the pipe 2m below the road surface to minimize the traffic impact.

### Pipe joints:

- 1) Socket & Spigot joint
- 2) Flanged joint.
- 3) Mechanical joint.
- 4) Flexible joint.
- 5) Expansion joint.

## Socket and Spigot joint

The cast iron pipes which are to be joined by the 'socket and spigot' joint are made in such a way that one of their end is enlarged whereas another end is normal.

Enlarged joint end is called socket or bell. while the normal end is spigot. The spigot is fitted in to the socket.

A few few strands of jute are wrapped around the spigot before inserting it into the socket and then the remaining space is between socket and the spigot is finally filled with molten lead. and thus making a water tight joint.

## 2) Flanged joint :-

This joints are used for Pumping station, and at other locations disjoints the pipe.

Cast Iron pipe length to be jointed by this, are joint are cast in such that way as to have flanges at both ends.

In case of steel pipe to be joined by such joint, flanges are separately cast and then screwed down both ends respective pipe length.

Two flanges are brought together, keeping a rubber washer in b/w them, so as to make them water tight. They are then fixed by means of nuts and bolts.

These joints are rigid but strong. They are expensive and mostly used for indoor works.

### 3) Mechanical joint :-

⇒ This joint is used when join the plain ends of cast iron pipes.

⇒ A special type of metallic collar is then fitted and tightened over the abutting ends, thus forming a mechanical joint.

⇒ One of the most commonly used type of a mechanical joint is a dresser coupling, a gasket and an iron ring are slipped over each of the abutting ends of the pipe.

⇒ These joints are strong and rigid.

Useful for pipes to be carried over bridges or below bridges in hangers.

## 4) Flexible joint :-

⇒ are used for where large scale flexibilities are required.

Ex ⇒ Pipes are laid in river with uneven beds, large scale settlement may break the ordinary type of joints.

⇒ While laying pipes on curve, the provided joints must be flexible, otherwise they may break.

⇒ The socket is spherical, and the spigot though plain having a bead at the end.

⇒ A retainer ring is placed over the bead, which keeps the special rubber gasket.

⇒ A split cast iron 'gland' ring is then placed over it, they are then tightened by means of nuts and bolts.

## 5) Expansion joint.

⇒ Are provided at suitable interval in the pipeline, so as to counteract the thermal stress produced due to temperature variations.

⇒ For providing expansion joints in cast iron pipes, the socket end is cast flanged and the spigot end is plain.

⇒ The socket end is connected rigidly to an annular ring which can slide freely over the spigot end.

## Pipe materials :-

- (i) Cast Iron , (ii) steel Pipes , (iii) RCC Pipes
- (iv) heavy steel Pipes , (v) vitrified clay Pipes , (vi) Plastic Pipes .
- (vii) Asbestos cement Pipes .

## Selection of Pipe material :-

- i) economy .
- ii) Working Pressure
- iii) maximum Permissible capacity ,
- iv) size ,
- v) Availability of materials and labour for their construction .

### i) Cast Iron Pipes :-

- i) widely used for city water supplies .
- ii) They are sufficiently resistant to corrosion .
- iii) May last as long as 100 years or so .
- (iv) 100% stronger than in tension and 50% stronger in rupture

stronger in rupture

(v) small service line for water supply are generally coated with zinc known as galvanized iron

Pipes .

Adv :

- ⇒ moderate in cost
- ⇒ Easy to join
- ⇒ Strong and durable
- ⇒ Corrosion resistant .

- Diadv :  $\Rightarrow$  later carrying capacity decrease with time.  
 $\rightarrow$  Not used for Pressure above  $700 \text{ kN/m}^2$ .  
 $\rightarrow$  When large, They are heavy and uncons<sub>-mical</sub>.  
 $\rightarrow$  Likely to break during transportation.

## ii) Steel Pipe :-

Small plates of varying thickness for withstand Pressure are generally bent and welded so as to make factory steel pipes.

Welded pipes are smoother and stronger than rivetted plates.

Since steel is strong in tension, even large size dia up to 6m can be made with thin shell, with stand higher Pressure.

Adv :-  $\Rightarrow$  frequently used for raw water trunk main.

$\Rightarrow$  Much stronger than cast iron.

$\Rightarrow$  Constructed for high Pressure and much lighter in weight.

$\Rightarrow$  Being cheaper, easier to construct and easy to transport.

Disadv :-  $\Rightarrow$  Not adopted to withstand external load of backfill.

$\Rightarrow$  Thinner walls and greater susceptible to corrosion.

$\Rightarrow$  high maintenance charge and shortened life.

$\Rightarrow$  Life of 25 - 50 years.

### iii) Cement Concrete Pipe :-

PCC are manufactured in small size 0.6m dia. they are reinforced with steel for large dia Pipe.

Adv!  $\Rightarrow$  Easily available in size larger 1.8m, and larger upto 4.5m.

$\Rightarrow$  may either be Prepared at site by transporting various ingredients. (cast insitu)

$\Rightarrow$  can be manufactured in factories and transported to site (Pre cast pipe).

$\Rightarrow$  Cast insitu pipes are useful, where the site condition are difficult and difficult to carry pipe.

### iii) b R.C.C Pipes :

Pipe having bar and mesh reinforcement and concrete poured by usual ordinary methods of concrete pouring and tamped.

Their thickness may vary from 2.5 to 6.5 cm. for pipes of varying from 0.1m to 1.2m.

Adv!  $\Rightarrow$  water tight joint

PCC for low heads  $150 \text{ kN/m}^2$

RCC for medium heads  $750 \text{ kN/m}^2$ .

PSC for larger heads

## Adv RCC!

- ⇒ Resist external compressive loads.
- ⇒ Not corroded from inside by normal Potable water, and outer soils.
- ⇒ Useful life of 75 years.
- ⇒ If laid under water, the empty do not float cause of their heavy weights.

## Disadv !:

- ⇒ Likely to corrode by ground water.
- ⇒ Difficult to repaired.
- ⇒ Cannot withstand high pressure.
- ⇒ heavy and bulk, difficult to transport.
- ⇒ Leaks due to shrinkage crack and porosity.

## 4) Hume Steel Pipe!

They consist of thin shell steel coated from inside with cement mortar by centrifugal process.

Thickness of inside coating 1.2 to 3.75 cm.

They are also coated from outside, to protect the steel from external soil action.

External coating of 2.5 cm - 3.5 cm.

They are heavy and difficult to handle.

5) Vitrified Clay: Not used as Pressure Pipe for carrying water. extensively used for carrying sewage and drainage at Partial depths.

These are free from corrosion and provide a smooth hydraulically efficient surface.

Not used for Pressure Pipe because clay is weak in tension.

Length - 0.6 to 1.2m.

## 6. Asbestos Pipes:-

Asbestos, silica, and cement are converted under Pressure to a dense homogeneous material Posses high strength called Asbestos cement

Available in diff sizes 10-90cm dia.

4m Length

4 grades - based on Pressure withstand.

### Adv:

⇒ light and easy to transport,

⇒ Easy to assemble without skilled labour.

⇒ high resistant to corrosion.

⇒ highly flexible 12° deflection in laying them

around curve.

⇒ very suitable to be used as small size distribution pipe

Disadv: ⇒ Costly,

⇒ Not much strength brittle and soft.

⇒ cannot used for transport petroleum.

## 1) Plastic Pipes!

⇒ Non-metallic pipe, made up of thermo plastic material.

⇒ Cheap, light weight, corrosion resistant durable, easy to joint.

⇒ Very large scale use in plumbing application, water supply, sewer pipe, irrigation and industrial use.

### Varieties:-

i) PVC,

ii) CPVC.

chlorinated poly vinyl chloride

iii) UPVC,

iv) HDPE.

unplasticized Poly vinyl chloride

High density Poly Ethylene

HDPE :-

50 years life.

zero maintenance.

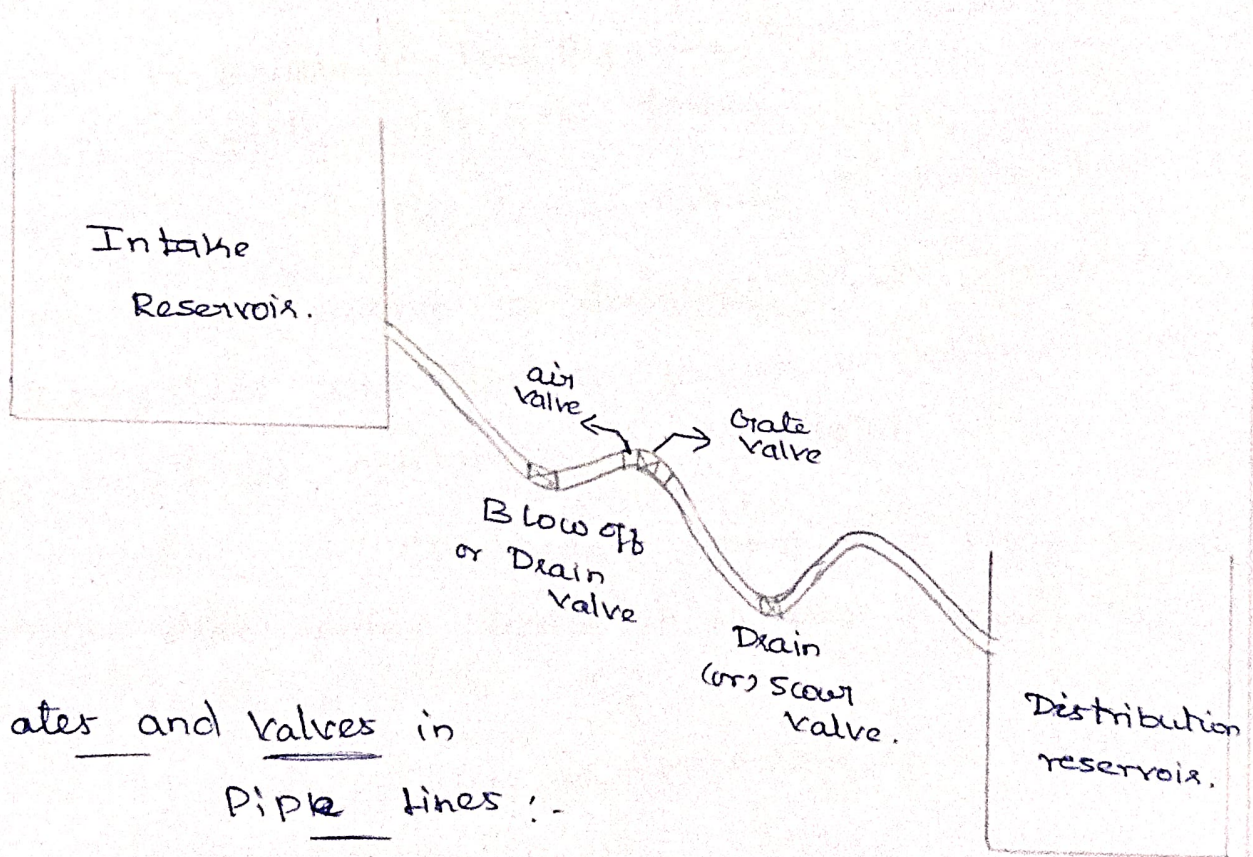
Re-usable

## Pipe Appurtanance :-

In order to isolate and drain the Pipe line sections for tests, inspections, cleaning and repair,

### Appurtanances :-

gates, valves, manhole, anchorages, insulation joints, expansion joint. are provided at various suitable places along the Pipe line.



### Gates and Valves in Pipe Lines :-

A large number of different types of valves are required for the proper functioning.

## Gate Valves :- / Sluice Valves :-

Used to regulate the flow of water through the pipe. They are similar to gate valves used in dams but are not so large.

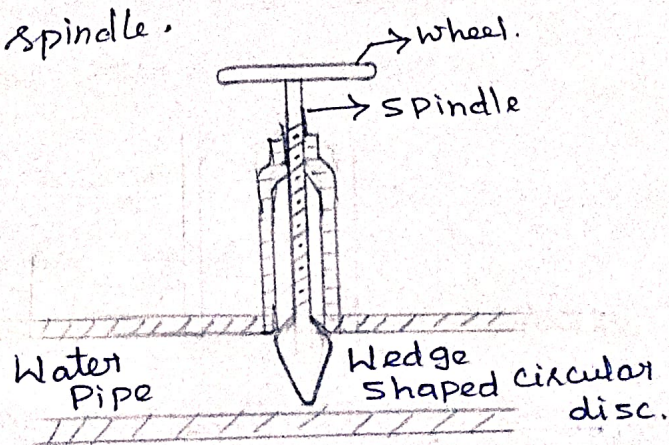
Located 3-5 km interval among the line. Usually placed at the summits of the pressure conduit.

They can be cheaper and less stronger materials in low pressure point. They can be operate easily with less force.

The valve made of <sup>cast</sup> ~~sluice~~ iron with brass, bronze or stainless steel. The ends of the valves are properly jointed on both side of pipe length by suitable standard joint.

The valve consist of a wedge shaped circular disc fitted closely in a recess against the opening in the valve.

This is connected to a wheel by means of threaded spindle.



## Air Valve :-

Special kind of valve which are generally placed along the pipe line at 'summit' on both sides of the sluice valves, and also on the downstream side of all other sluice valves.

They ensure the safety of pipe against collapse.

They will protect the pipe against the negative pressure, which may be developed, when during steady flow, such a valve will open out automatically as soon as the pressure in the pipe falls below a certain fixed predetermined value, allowing air to enter the pipe, is called air inlet valve.

The accumulated air obstruct the free flow of water and the pipe may get air locked.

Air relief valves required to be provided at all summits to remove the accumulated air under such circumstances.

Single orifice air valve used as air inlet as well as air relief valve.

## Blow off, Drain or Scow Valve :-

In order to remove the entire water from within a pipe, small gated-off taken provided at lower points. These valves are known as Blow off valve.

These valves are generally necessary at low level points for completely emptying the pipe for inspection, repairs, etc.

### Pressure-relief valve :-

Water hammer Pressure in Pressure Pipes can be reduced by using Pressure relief valve.

Due to opening of this valve, certain water will get out of the pipe, and thus reducing the pressure in the pipe.

### Check valves or Reflex valves :-

This is also called as 'non-return valves' because they prevent water to flow back in the opposite direction.

They may be installed on the delivery side of the pumping set, so as to prevent the back flow of stored water, when the pump is stopped.

Check valves are also installed on pump discharges to reduce water hammer force on the pump. Such a valve may be a simple swing check or ball device.

## Manhole:

manholes are provided at suitable intervals along the pipe line, so as to help its laying, and to serve for inspection and repair.

They are generally provided on large pipe line bringing water from the source to the city at intervals of about 300-600m.

## Anchorage:-

The anchors consisting of cement concrete. The pipe must be well bounded to these anchors by angle iron welded on to the pipe.

In cast iron pipes, the anchors may take the form of lugs, cast on such pipes and their fittings, to hold tie rods that prevent movement of the pipe line.

### 3. Water Treatment

⇒ The available raw water must be treated and Purified before they can be supplied to the general Public for their domestic, Industrial or any other uses.

⇒ The extent of treatment required to be given to a Particular water depends upon the characteristics and quality of the available water, and also upon the quality requirements for the uses.

#### Methods of Purification :-

- i) Screening.
- ii) Plain Sedimentation.
- iii) Sedimentation aided with Coagulation.
- iv) Filtration.
- v) Disinfection.
- vi) Aeration.
- vii) Softening.
- viii) Miscellaneous.

## Screening :

Most of the big and visible objects, such as trees, branches, sticks, vegetation, fish, etc., present in raw water of surface sources can be removed by screening.

## Plain Sedimentation :-

The coarser suspended materials can then be removed by letting the water settle in sedimentation basin. The process is called Plain Sedimentation.

## Sedimentation Aided with Coagulation :-

The effectiveness of sedimentation may be increased by mixing certain chemicals with the water, so as to form flocculent precipitates, which carries the suspended particles as it settles. The process is called chemical coagulation.

## Filteration :

The finer particles in suspension, which may avoid settling in sedimentation basin even after adding chemical, may then be removed by filtering process.

## Disinfection:-

The filtered water which may still contain pathogenic bacteria is then made bacteria proof by adding certain chemicals such as chlorine, etc. This process of killing germs is called Disinfection.

## Aeration :

The resulting water from Disinfection process become safe, yet, may not be attractive to the tongue of the consumer. Unpleasant water taste and odour then have to be removed by adding certain chemical compounds such as activated carbon or by using ozone. This process is called aeration.

## Softening :

The resulting water may sometimes be much harder than permissible and may, therefore, have to be softened by a process called softening.

Sometimes, the resulting water may be given further treatment, such as fluoridation, liming, recarbonation, desalination.

## FLOCCULATION :-

The mechanically agitated mixing basin equipped with is provided with the best type of mixing as also the flocculating devices.

The chemical added through to the raw water is vigorously mixed and agitated by a flash mixer. For its rapid dispersion in raw water, and the raw water is then transferred to a flocculation tank provided with a slow mixer.

Mixing therefore involves high degree of turbulence and power dissipation. A typical mixing basin provided with a flash mixer consist of a rectangular tank which is provided with a impeller shaft.

The impeller is driven by an electric motor, and it revolves at a high speed inside the tank.

The coagulant is brought by the coagulation pipe and is discharged just under the rotating bar.

The raw water is separately brought from the inlet end and is deflected towards the moving impeller by a deflecting wall.

The thoroughly mixed water is taken out from the outlet end. A drain valve is also provided to remove the sludge from the bottom of fresh mixer.

The impellers speed is generally kept between 100 to 120 r.p.m. and the usual values of detention period may vary between  $\frac{1}{2}$  to 2 minutes.

Power required for flash mixing vary from 2-5 kW/m<sup>3</sup>.min.

Power input in mixing and flocculation is frequently expressed in terms of temporal mean velocity gradient. ( $G'$ )

$$G' = \left[ \frac{P}{\mu \cdot V} \right]^{1/2}$$

$G'$  - Velocity gradient (1/sec)

$P$  - Power dissipated in Watts (ie)  $\text{Nm/s}$

$\mu$  - Dynamic Viscosity of raw water  
in  $\text{N.s/m}^2$ .

$V$  - Vol. of raw water to which  $P$  is  
applied ( $\text{m}^3$ ).

Unit of  $G'$   $\Rightarrow$   $\text{1/s}$ .

For Rapid mixing the Product is  $G'T^2$   
should be 30,000 to 60,000

$T$  - detention Period 60-120sec.

## FLACCUATOR:-

The best floc will form, when the mixture of water and coagulant are violently agitated followed by a relatively slow and gentle stirring to permit build up and agglomeration of the floc particles.

From the mixing basin, the water is taken to flocculation tank called flocculation where it is given a slow stirring motion.

Rectangular tanks fitted with paddles operated by electric motor can best serve this purpose, although even plain flocculation chamber with controlled flow velocities are also possible.

The paddles usually rotate a speed of about 2 to 3 rpm.

The usual values of detention period for this tank 20-60 mins. Value of velocity gradient  $G'$  ranges between 20-80  $\text{Vs}^{-1}$ .

The clear distance between paddles and wall is about 75 to 30 cm.

## Sedimentation tank:-

Most of the suspended impurities present in water do have a specific gravity greater than that of water.

In still water, these impurities will therefore tend to settle down under gravity, although in normal raw supplies they remain in suspension, because of the turbulence in water.

By offering storage to the water, these impurities tend to settle down at the bottom of tank. This is the principal behind the sedimentation.

Settling velocity of the spherical particle is expressed by Stokes law, its based on the velocity of flow, the viscosity of water, and the size and shape of the particle.

$$v_s = \frac{g}{18} (G-1) \frac{d^2}{\nu}$$

$$d < 0.1 \text{ mm.}$$

$\nu$  = kinematic viscosity of water.

## Overflow Velocity :-

It is that flow velocity at which the tank is designed to operate.

(vs) The rate at which the particle is settling is called 'settling velocity', and the velocity of the liquid rising is called  $v_0$  overflow rate.

$$v_s \geq v_0 \quad - \quad 100\% \text{ removal}$$

$$v_s < v_0 \quad - \quad 0\% \text{ removal.}$$

the water is flowing over the top of the tank into the weir system is referred to as surface loading rate. ( $\text{m}^3/\text{d}$ ).

$$v_0 = \frac{\text{Discharge}}{\text{Surface area}} = \frac{\text{Volume/Time}}{\text{Surface area.}}$$

$$\frac{\text{depth}}{\text{time}} = \text{m/s}$$

If  $Q$  is discharge entering the basin, the flow velocity  $v$ .

$$v = Q / B \times H.$$

$B$  = width of the tank

$H$  = Depth of the tank.

Settling velocity of the Particle.

$$v_s = \frac{Q}{Bt}$$

Over flow rate varies between 12-18 m<sup>3</sup>/d 1 m<sup>2</sup> of Plan area (Plain sedimentation).

For aided with coagulation 24-30 m<sup>3</sup>/d 1 m<sup>2</sup> of Plan area.

Depth of the tank ranges between 3.0 m to 4.5 m.

1.5 m as minimum and 6 m as maximum.

Detention Period: Ratio of the Volume of the basin to the rate of flow through the basin.

Detention time  $t$  for a Rectangular tank

$$= \frac{\text{Volume of the tank}}{\text{Rate of flow}}$$

$$= \frac{B \times H}{Q}$$

circular tanks.

$$= \frac{d^2 (0.011d + 0.785H)}{Q}$$

Detention Period: Avg Theoretical time required for the water to flow through the tank length. time, which would be required by the flow of water to fill the tank.

Plain Sedimentation = 4-8 hours.

coagulants are added = 2-4 hours.

width of the tank kept normally 10m, not exceeds 12m.

Length of the tank = 4 times the width of the tank.

flow velocity = 0.15 m/min to 0.9 m/min

Flowing through Period!

The actual average time, which a batch of water takes in passing through a settling tank, called 'flowing through Period', always less than detention Period.

Displacement efficiency - ratio of flowing through period, to the 'detention Period'

varies between 0.25 to 0.50, in normal sedimentation.

## Scour Velocity:-

=> to limit the overflow velocity in the sedimentation tank as to cause the settlement of all the particles smaller than 'd'.

=> to confirm that this flow velocity should not be cause scour of the settled particles.

=> The flow velocity should not be more than scour velocity, as to cause the uplift of the particle, which have settled.

$$\text{Scour velocity } V_d = \sqrt{\frac{8B}{f'} \cdot g(G-1)d}$$

$B = 0.04$  for ungranular sand  
 $0.06$  for non-ungranular material

$f'$  = Darcy weisbach friction factor.  
 $0.025$  to  $0.03$  for settling tanks.

The maximum daily demand at a water Purification Plant has been estimated as 12MLD. Design the dimensions of a suitable sedimentation tank for the raw supplies, assuming a detention period of 6 hours and the velocity of flow as 20cm/min.

Sol:

Quantity of water to be treated, in 24 hours.

$$= 12 \times 10^6 \text{ L}$$

Quantity of water to be treated during the detention period of 6 hours.

$$= \left[ \frac{12 \times 10^6}{24} \times 6 \right] = 3 \times 10^6 \text{ Lit}$$

$$= 3000 \text{ m}^3$$

The capacity of the tank required = 3000 m<sup>3</sup>.

Velocity of flow = 0.20 m/min.

Length of the tank

$$= \text{velocity of flow} \times \text{DT}$$

$$= 0.2 \times 6 \times 60$$

$$= 72 \text{ m}$$

Cross-sectional area of the tank required .

$$= \frac{\text{Capacity of the tanks}}{\text{length of tank}} = \frac{3000}{72}$$
$$= 41.7 \text{ m}^2.$$

Assume the water depth in the tank as  $4 \text{ m}$ .

$$\text{width of the tank} = \frac{41.7 \text{ m}^2}{4}$$

$$= 10.42 \text{ m} \approx 10.5 \text{ m}.$$

Using a free-board  $0.5 \text{ m}$ , of overall depth .

$$= 4 + 0.5 \text{ m} = 4.5 \text{ m}.$$

Rectangular Sedimentation tank with an overall size of  $72 \text{ m} \times 10.5 \text{ m} \times 4.5 \text{ m}$ .

## FILTRATION !.

The Process of Passing the water through the beds of such granular (sand) materials called filtration.

may help in removing colour, odour, turbidity and some Pathogenic bacteria from the water.

- (i) Slow sand gravity filters.
- (ii) Rapid sand gravity filters.

A third type rapid sand filters work under Pressure and is known as a Pressure filter. used for small plants, individual industrial supply or swimming pools.

### Sand !

- (i) It should be free from dirt and other impurities.
- (ii) It should be uniform in nature and size.
- (iii) It should be hard and resistant.
- (iv) not to lose more than 5% of its weight after placed in hydrochloric acid for 24 hours.

The size of sand is measured and expressed by the term called effective size,  $D_{10}$ .

$D_{10}$  - The size of the sieve in mm through which 10% of the sample sand will pass.

$D_{10}$  - Slow sand filter - 0.2 to 0.4 mm.

Rapid sand filter - 0.35 to 0.55 mm.

Uniformity in size or degree of variation in sizes of particles is measured in mm through and expressed by the term called 'uniformity coefficient'.

$$\frac{D_{60}}{D_{10}} = \frac{\text{sieve size in mm } 60\% \text{ of sample Pass}}{\text{effective size of sand}}$$

Slow sand filter  $\frac{D_{60}}{D_{10}} = 1.8 \text{ to } 2.5$ .

Rapid sand filter  $\frac{D_{60}}{D_{10}} = 1.3 \text{ to } 1.7$ .

Comparison of Slow sand filter and Rapid sand filter.

Item	Slow sand filter	Rapid sand filter.
Pre-treatment requirement	Effluent either from plain sedimentation tank or raw water without any treatment, and coagulation is not at all required.	Coagulation, flocculation and sedimentation is a must.
Base material	The gravel base supports the sand. It varies from 3 to 5mm and 30-75cm in depth.	The gravel base supports sand and also distributes the wash water uniformly on the surface of sand. It varies from 3-40mm in size, 60-90cm depth.

Filter Sand	The effective size of Sand 0.2 - 0.4 mm, uniformity coefficient 1.8 to 3.0	$D_{10} = 0.35 \text{ to } 0.55$ $\frac{D_{60}}{D_{10}} = 1.2 \text{ to } 1.8$
	The grain size distribution is generally uniform throughout the depth of except that top 10 - 15 cm may be laid finer variety.	The sand is laid in layers with smallest grain at top and coarser at the bottom.
Under drainage system.	laid in order to receive filtered water. Open jointed pipes or drains used.	Laid in order to receive filtered water also pass water for back washing. Perforated pipe laterals discharging into mains.
Size of Each Unit.	Large, such as (30m x 60m). The area varying from 100 - 2000 m <sup>2</sup> or more.	Small such as 5m x 8m area varying from 10 - 80 m <sup>2</sup> .
Rate of filtration.	Small such as 100 - 200 lit/hr/m <sup>2</sup> .	Large such as 3000 - 6000 lit/hr/m <sup>2</sup> .
Economy.	High initial cost of both material and land, and low cost of maintenance and operation.	Low initial cost, but higher cost of operation and maintenance, it is cheaper and economical.
Depreciation Cost	Relatively low	Relatively high.

Efficiency.	<p>Very efficient in removing bacteria 98%-99%.</p> <p>less in removing colour</p> <p>They cannot handle turbid waters containing turbidities more than 50mg/l</p>	<p>Less efficient in removing bacteria 80-90%.</p> <p>Very efficient in removing colour. turbidity removal is high.</p>
Flexibility.	<p>Not flexible for meeting variations in demand.</p>	<p>Quite flexible for meeting reasonable variations in demand.</p>
Suitability and adaptability.	<p>Adopted for small village supplies, especially at hotter places where no covers required to protect the filters from freezing.</p>	<p>They are widely and almost universally adopted for treating public supplies,</p>
Post treatment required (if any)	<p>Almost pure water is obtained. However, it may be disinfected slightly to make it completely safe.</p>	<p>Disinfection is a must and some other miscellaneous treatment may be given.</p>
Ease in construction.	<p>Simple.</p>	<p>Complicated as under drainage is to be properly designed.</p>
Skilled supervision (if req)	<p>Not required.</p>	<p>Essential.</p>
Loss of Head.	<p>Approximately 0.1m is the initial loss, 0.8 to 1.2m is the final limit, when cleaning is required.</p>	<p>Approximately 0.3m is initial. 2.5 to 3.5m is final limit, when cleaning is required.</p>

Method  
of cleaning.

Scraping and removing  
top 1.5 to 3cm thick  
layer and washing down  
by hoses.

Laborious method.

Qty. of  
wash water  
Required

Very small amount of  
wash water varying from  
0.2 - 0.6% of the total  
water filtered is generally  
needed.

Period  
of cleaning.

cleaned at intervals  
of 1 - 3 months.

Agitating the sand  
grains and backwashing  
with or without compressed  
air.

Short and Easy method.

Large amount of wash  
water 1 - 5% of the total  
water filtered is generally  
required.

Cleaned frequently at  
intervals of 1 - 3 days.

## Removal of Iron and manganese from water:

Iron and manganese salts are generally found dissolved together in well water in invisible dissolved state.

When their content exceeds about 0.3 mg/l and 0.05 mg/l respectively, they become objectionable due to the following reasons:

⇒ They cause discolouration of cloths, washed in such waters due to deposition of red/brown coloured oxides of iron/manganese.

⇒ They cause incrustation of the water-mains due to deposition of ferric hydroxides and manganese oxides.

⇒ They make the water unpleasant in taste.

⇒ The reduced iron in water Promotes the growth of autotrophic bacteria in the distribution mains.

Elimination of iron bacteria is generally difficult and expensive.

Iron and manganese may be Present in either combination with organic matter. When Present without combination with organic matter they can be easily removed by aeration, followed by

by coagulation, sedimentation and filtration.

During aeration, the soluble ferrous and manganese compounds present in the water may get oxidised into insoluble ferric and manganic compounds, which can be sedimented out easily.

On the other hand, when iron and manganese are present in combination with organic matter, it becomes difficult to break the bond b/w them and cause their removal.

The bond may be removed either by adding lime and thereby increasing pH values of water to about 8.5 to 9. or by adding chlorine or Potassium Permanganate.

Manganese zeolite: a natural green sand, coated with manganese dioxide, can also be used for removing soluble iron and manganese from solution. After the zeolite becomes saturated with metal ions, it can be regenerated by backwashing with Potassium Permanganate.

## Fluoridation:-

Fluorides in drinking water, must neither be totally absent nor should exceed an optimum value of 1mg/l.

Fluorides are added to the waters, found deficient in fluoride concentrations, under a process known as 'Fluoridation'.

The fluorides concentration in a given water exceeds the limiting value of 1 to 2.5mg/l the fluorides are removed from water is known as Defluoridation.

Excess intake of fluoride cause dental fluorosis, skeletal fluorosis, or non skeletal fluorosis.

## Methods of Defluoridation:-

- 1) Absorption by activated alumina.  
(Prasanth technology)
- 2) Ion Exchange adsorption Method.
- 3) Nalgonda technique.
- 4) Reverse Osmosis.

## Adsorption by Activated Alumina:-

In this method, the raw water containing high contents of fluoride, is passed through the insoluble granular beds of substance like activated alumina.

which adsorbs fluoride from the percolating water, giving out defluoridated water.

Excellent medium for removal of excess fluoride.

It is highly selective to fluoride in the presence of sulphates and chlorides, when compared to synthetic ion exchange resins.

pH = 5-7 lower value of pH is more effective for its removal.

The activated alumina (after becoming saturated with adsorbed fluoride, can be cleaned and regenerated by back washing with 1% caustic soda solution.

## Ion exchange Adsorption Method:-

The Ion Exchange Process is almost similar to that used for removing hardness from water.

Uses a strong base anion exchange resin in the chloride form.

The water passes through the bed of the resin contained in a pressure vessel, fluorides and other anions like arsenic, nitrate, etc., present in the water are exchanged with chloride ions into the resin.

The arsenic and nitrate also get removed in the process.

When the resin gets saturated with anions like fluoride, nitrate, etc., as indicated by their increased concentration in the out flowing water.

The same can be cleaned and regenerated by 5-10% sodium chloride solution, and the bed is returned to service.

The capacity of a plant based on this technology may range from 500 l/h. to 5000 l/h.

The method is found to be very costly and good 'after sales service' in village do not become easily available.

The safe disposal of waste water from regeneration process is required.

## Nalgonda Technique!

ground water containing excess fluorides is treated by Nalgonda technique.

This technique is found to be simpler and economical than the above mentioned fixed-bed ion exchange process.

It does not involve regeneration of media, and employs chemical which are chemically readily available, and easy to operate and maintain, using local skills.

Nalgonda technique, not only help in the removal of fluoride, but also helps in removing colour, odour, turbidity, bacteria and organic contaminants from raw supplies.

Alumina salts used for removing fluoride. The raw water is firstly mixed with adequate amount of lime ( $\text{CaO}$ ) or sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) and thoroughly mixed.

Alum solution is then added and water is stirred slowly for about 10 mins, and allowed to settle for nearly one hour.

The precipitated sludge is discarded and the clear supernatant containing permissible amount of fluoride is withdrawn for use.

## Reverse Osmosis Process:-

The raw water is passed through a semi permeable membrane barrier, which permits the flow of clear water through itself and blocks the flow of salts, including fluorides.

This method is generally adopted for desalination, removal of salts from water.

rarely used for defluoridation of village water supplies due to prohibitive high cost and poor after sales service of machines using such a treatment technology, capable of produce high fluoride removal efficiency, without the use of any chemical.

## Corrosion:

The well pipe is gradually destroyed by corrosion due to the action of acidic water.

When chlorides and sulphates are present in water, the well pipe will definitely get corroded.

Thicker pipes may be used to avoid corrosion. Stainless steel strainers will be most suitable but are very costly.

### Corrosion Control:-

- i) Reducing the drawdown and the pumping rate.
- ii) Reducing flow velocity
- iii) Using thicker pipe.
- iv) Corrosion resistant material used in pipes.
- v) by using corrosion resistant coating on

Pipe.

## UNIT - IV - ADVANCED WATER TREATMENT.

### Water softening :-

The reduction or removal of hardness from water is known as water softening.

- 1) Temporary hardness (or) carbonate hardness.
- 2) Permanent hardness (or) non carbonate hardness.

### Temporary Hardness :-

Carbonate and bicarbonates of calcium and magnesium, can be removed by boiling or by adding lime.

### Permanent hardness :-

Caused by the sulphates, chlorides and nitrates of calcium and magnesium. Has to be removed by special methods of water softening.

Permissible Hardness for Public supplies normally = 75 mg/l to 115 mg/l.

### Methods of removing Temporary Hardness :-

#### 1) Boiling :

Calcium carbonates slightly soluble in water, usually exist in water as calcium carbonate because, it easily dissolves in natural water containing  $\text{CO}_2$ . Such a water is boiled, the  $\text{CO}_2$  gas will get out, leading to the precipitation

## Disadvantages:-

- ⇒ More Pre-treatment required.
- ⇒ Maintenance cost is high.
- Membrane fouling.
- ⇒ Direct effect of salinity.

## Adsorption :-

Adsorption is a surface phenomenon & consequence of surface energy.

The surface of liquids/solids always have tendency to attract & retain the molecular species with which it comes in contact. This phenomenon is known as adsorption.

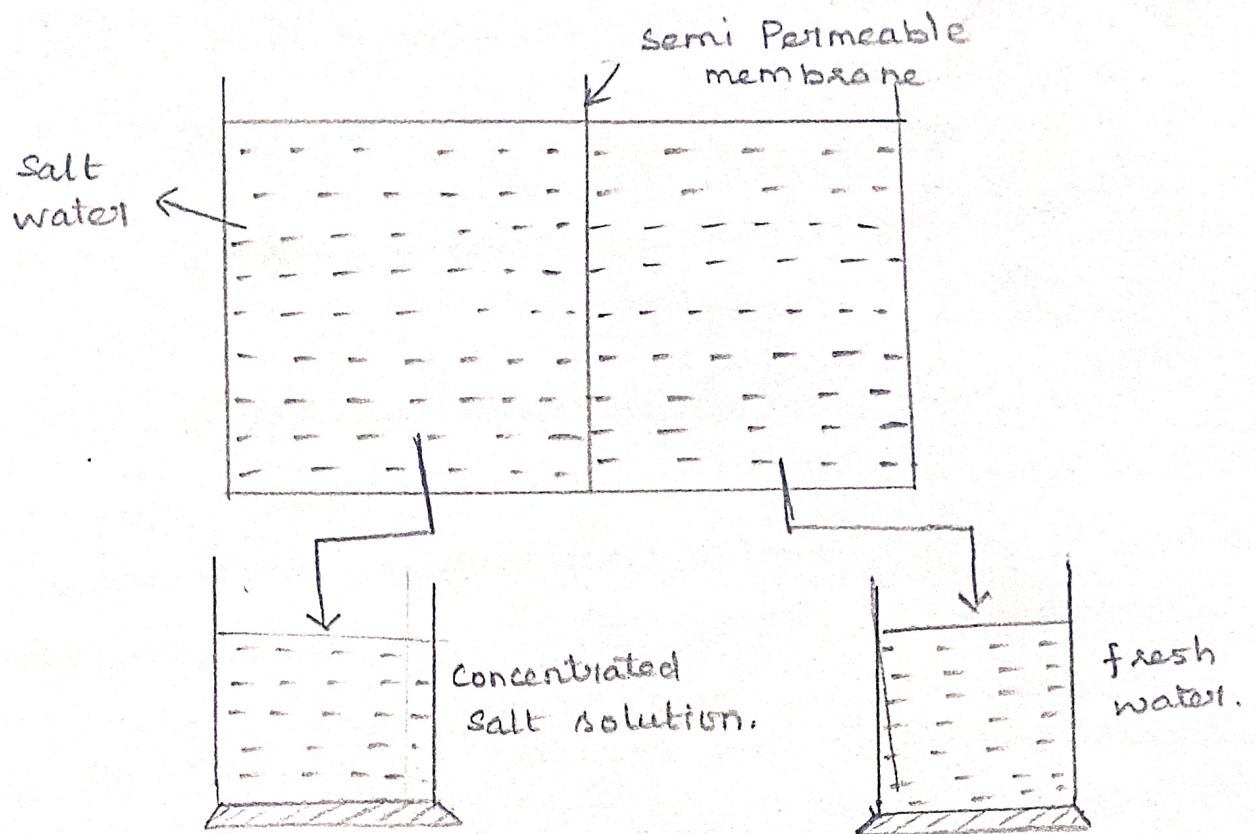
Adsorption can be defined as a process in which atoms move from a bulk phase onto a solid or liquid surface.

**Adsorbate** - The substance which is adsorbed on the surface

**Adsorbent** - The substance on which surface the adsorbate is adsorbed.

## Adsorbents !

Activated Carbon, Activated Alumina, Silica gel, Synthetic zeolite, clay, Polymer & Resin.



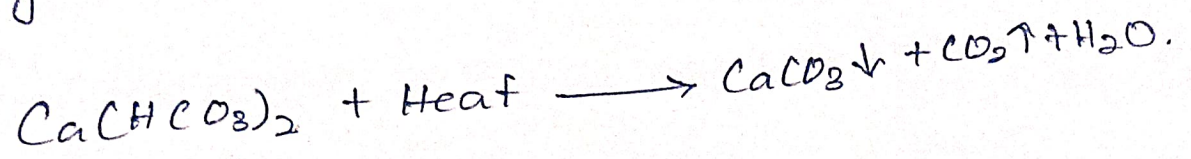
The Osmotic Pressure is Proportional to the TDS of water, and a Pressure of atleast twice the osmotic pressure is required to achieve an economically feasible flow.

Semi Permeable membrane is thin Process is hence thin but dense and strong enough to withstand the high external Pressure.

### Advantages:-

- ⇒ Suitable for desalinating both sea water as well as brackish ground water.
- ⇒ Flexibility in regards of quantity and quality.
- ⇒ operating cost is low, less environmental Impact.

of  $\text{CaCO}_3$ , which can be sedimented out in settling tank. \*

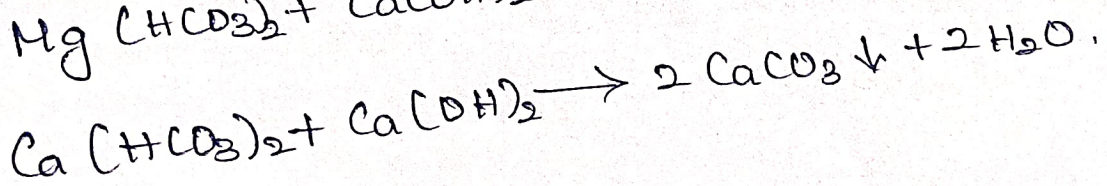
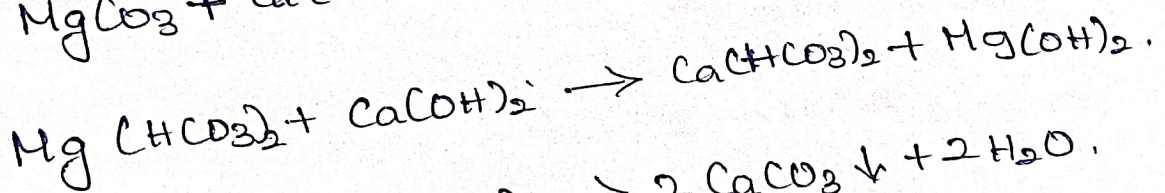
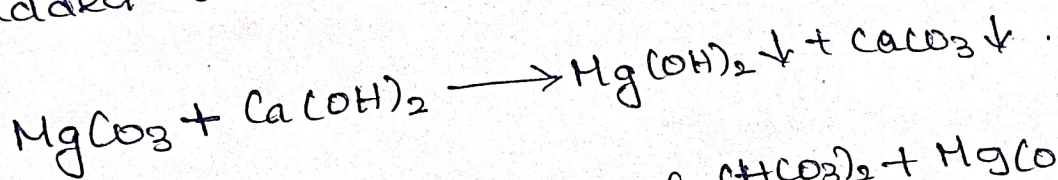


The magnesium bicarbonates and magnesium carbonate, cannot be satisfactorily removed under the above type of reaction. Since  $\text{MgCO}_3$  is fairly soluble in water.

Boiling cannot remove the temporary hardness caused by magnesium.

Addition of lime :-

lime ( $\text{CaO}$ ), generally hydrated lime [ $\text{Ca}(\text{OH})_2$ ] is added to the water.



The calcium carbonate and magnesium hydroxides are precipitated and can be removed in the sedimentation tank.

This method is generally adopted for softening water which contain only temporary hardness.

## Methods of Removing Permanent Hardness.

Permanent hardness is more permanent, difficult to remove.

It can be removed by certain special methods, generally called "water softening" methods.

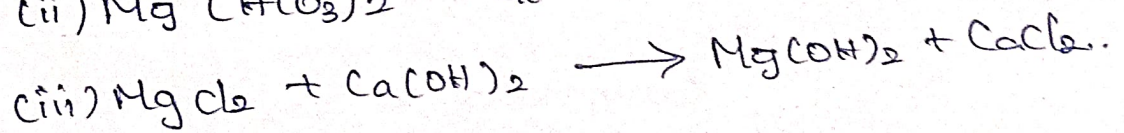
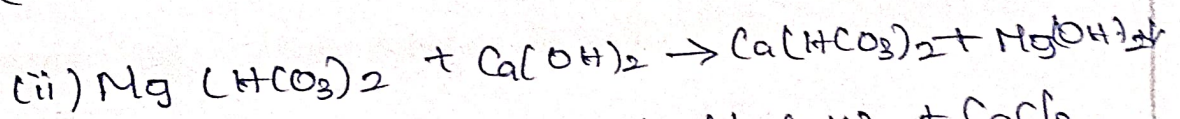
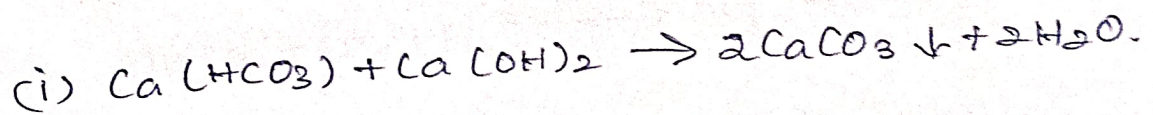
1) Lime soda Process. 2) Base Exchange Process.

3) Demineralisation Process.

### Lime Soda Process:-

Lime and soda ash are added to the hard water; which react with the calcium and magnesium salts, so as to form insoluble precipitates of calcium carbonate and magnesium hydroxides:

These precipitates can be sedimented out in a sedimentation tank.



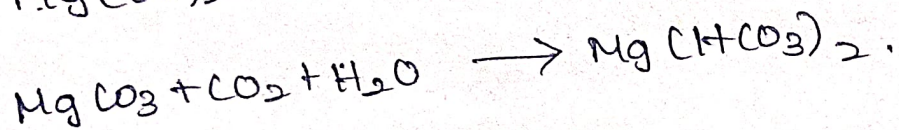
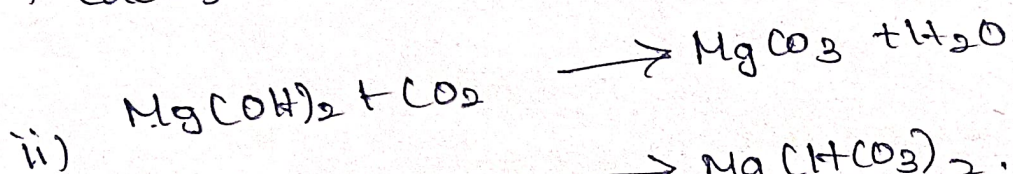
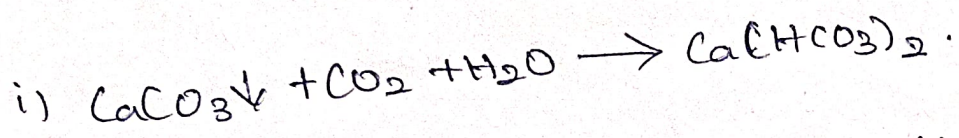
It can be easily seen that lime helps in removing the entire carbonate hardness and it react with non-carbonate hardness of <sup>Mg converted to</sup> Ca.

The carbonate hardness of Ca is finally removed by soda.

A little quantity may remain as finely divided particles, and may cause trouble by getting deposited on the filter to cause enlargement of the sand grains. called incrustation of filter media;

To prevent this, it is generally necessary that the water be recarbonated by passing  $\text{CO}_2$  gas through it, as it leaves the sedimentation tank.

In the recarbonation process, the insoluble carbonates combine with the carbon dioxide to again form the soluble bicarbonates.



Advantages of lime soda process :-

1) The process is economical.

2) It can be easily combined with the usual water treatment method without much cost.

3) Lime and soda are added in addition to the coagulants. Lesser quantity of coagulant is required.

## Zeolite or Base Exchange Process for Removing

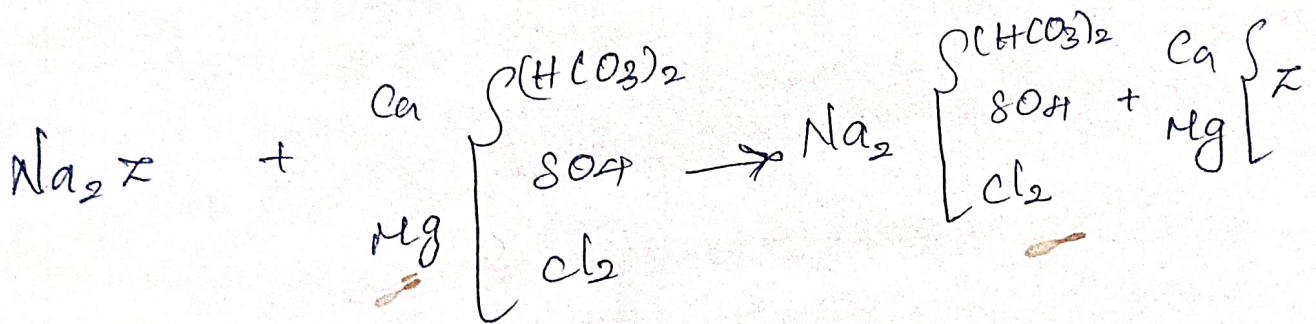
Hardness :-

zeolites are natural salts or clays, which are hydrated silicates of sodium and aluminium.  
 $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x \cdot \text{SiO}_2 \cdot y \cdot \text{H}_2\text{O}$ .

zeolites are Resins, also manufactured synthetically.

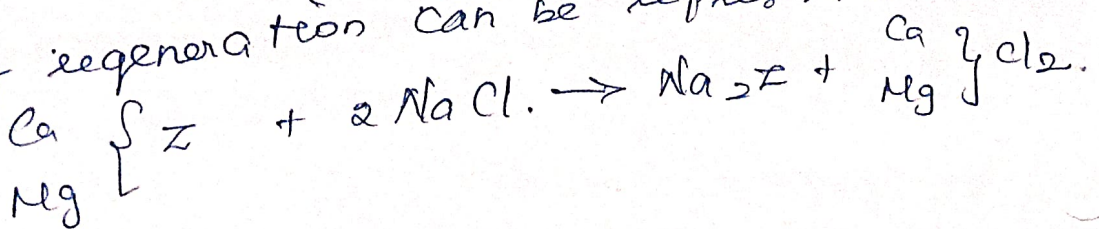
Resin have the excellent property of exchanging their cations.

During softening operation, the sodium ions of the zeolite get replaced by the calcium and magnesium ions present in hard water.



The Calcium and Magnesium zeolite can be regenerated into active sodium zeolite by treating it with 5-10% solution of sodium chloride.

The exchange reaction that take place during regeneration can be represented as :-



A zeolite softener resembles a sand filter in which the filtering medium is a zeolite rather than sand.

The hard water enters through the top and is evenly distributed on the entire zeolite bed.

When a significant portion of the sodium in the zeolite has been replaced by Ca & Mg it is regenerated by first washing it with water by reversing the flow, and then treating it with 10% solution of brine.

The excess brine solution retained in the zeolite after the treatment is removed by again washing it with good water.

The regenerated zeolite can be used as fresh for softening.

Zeolite softeners may be either gravity or pressure filters.

Pressure type:-

The unit consists of a closed steel cylinder containing a bed of zeolite, 0.75m-2m thick.

The thicker bed has a greater capacity per unit area, and hence takes up less space and requires less water when washing is needed.

The rate of filtration is  $100-300 \text{ lit/m}^2/\text{min}$  for bed depths of  $0.75\text{m} - 2\text{m}$ .

The zeolite process will result in a water of zero hardness, which generally is not suitable for public supplies.

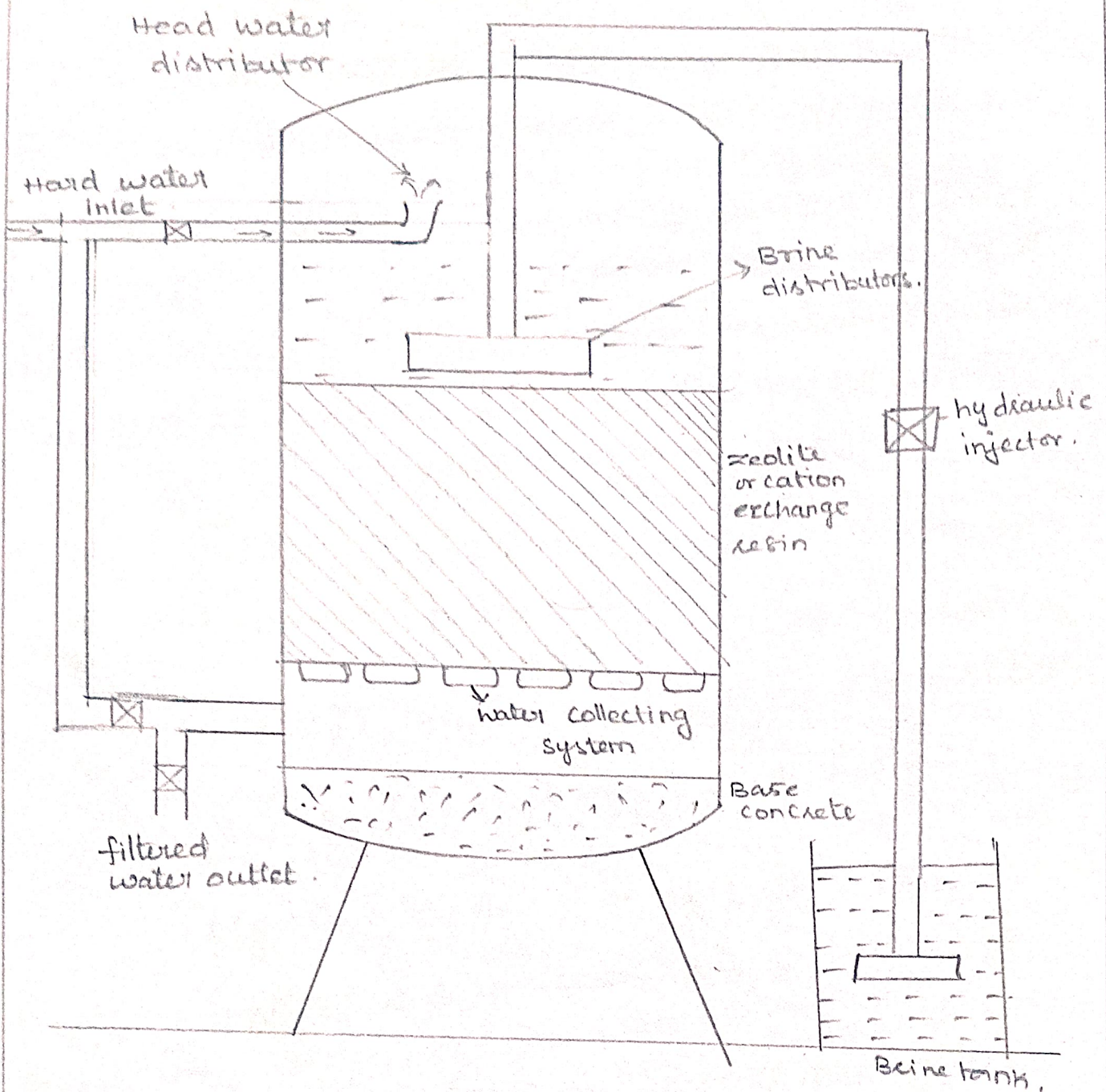
Only a portion of the water passing through the treatment plant is to be softened, and then mixed with unsoftened water to obtain the desired quality.

### Advantage:

- zero hardness can be obtained.
- Automatic & easy to operate.
- There is no problem of sludge disposal.
- Cost is quite less.
- Removes ferrous iron and manganese from water.

### Disadvantage :-

- Not suitable for treating highly turbid water.
- The process leaves sodium bicarbonate in water.
- It is costlier and unsuitable for treating water containing iron & manganese.



### Demineralization :-

Removing the minerals from the water.

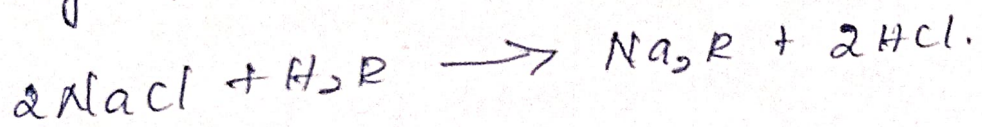
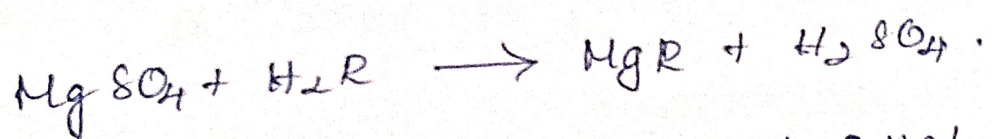
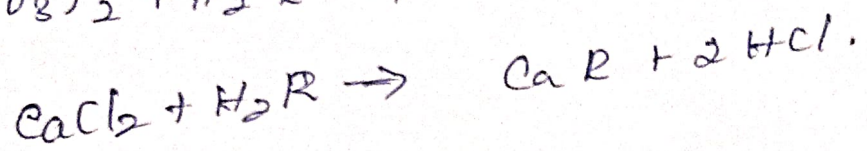
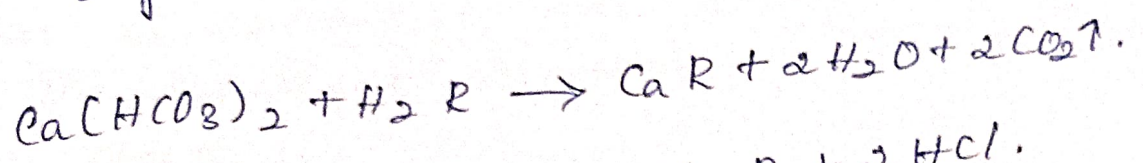
Since this process completely removing or reducing the mineral content by any desired extent, it is very suitable for producing water of any desired hardness or even mineral free water.

This demineralised water sometimes called de-ionised water, is as pure as distilled water and is very suitable for.

Industrial purpose, especially for steam raising in high pressure boiler.

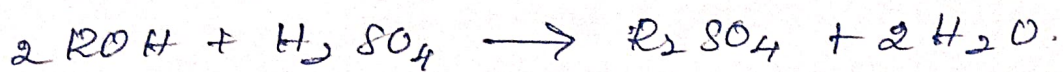
This complete removal of mineral present in water can be carried out by first passing the water through a bed cation exchange resin and then through a anion exchange resin.

The cation exchange resin having base exchange properties.  $H_2R$ . H - Hydrogen ions. and R - organic parts.



The water coming out of the cation exchanger will now contain diluted carbonic acid, hydrochloric acid, sulphuric acids, etc. and can be removed by passing the water through a bed of anion-exchange resin.

The anion exchange resin are formed by the condensation of amines with formaldehyde and are capable of replacing the anions with their hydroxyl ions  $ROH$ . OH - Hydroxyl ions.



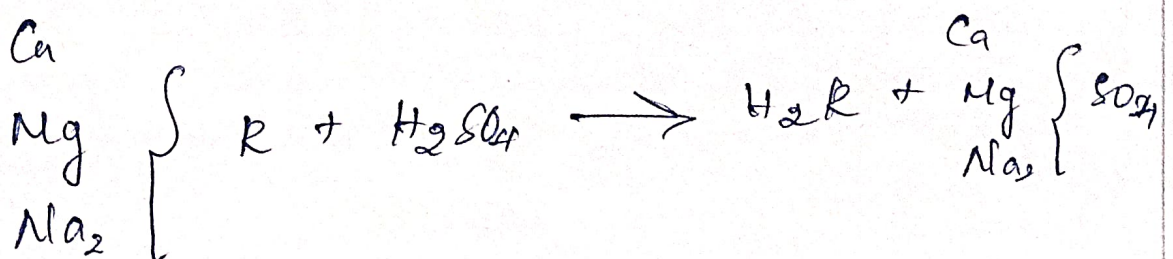
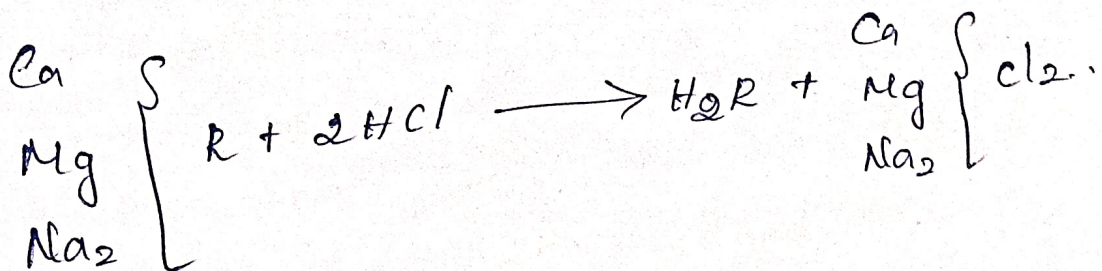
The water coming out from this anion exchanger will then be free from minerals.

The extent of removal will depend upon the strength and freshness of the resin used.

The completely demineralised water can sometimes be added to raw water, to obtain the resultant supplies of any desired mineral content.

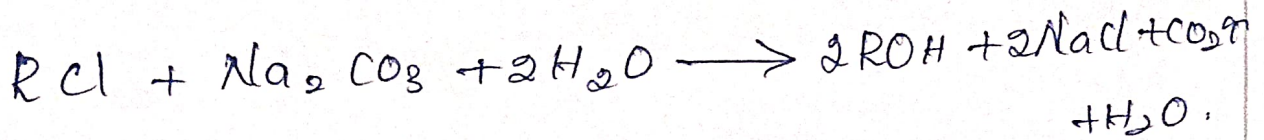
Regeneration of cation exchange resin:-

The exhausted cation exchange resins can be regenerated by treating them by dilute hydrochloric acid or sulphuric acid.



## Regeneration of anion exchange resin:-

The exhausted anion exchange resin can be regenerated by treating them with sodium carbonate solution.



## Desalination:-

Complete removal or reducing of salts and minerals from the water is called Desalination.

## Methods of Desalination:-

which are generally adopted for the conversion of salt water into the fresh water.

- 1.) Desalination by evaporation and distillation.
- 2.) Electrodialysis method.
- 3.) Reverse Osmosis method.
- 4.) Freezing Process.
- 5.) Solar distillation method.
- 6.) other methods.

## Desalination by reverse Osmosis Process:-

the water molecules and the salt ions are separated by forcing the salt solution against a 'Semi Permeable membrane', which permits the flow of water through itself but stops the salt.

In ordinary osmosis when salt solution is separated from pure water by a semi permeable membrane, ~~water~~ the pressure pure water flows across the membrane until the pressure on the pure water side becomes equal to the osmotic pressure of the salt solution,

Reverse Osmotic Process, the osmotic pressure is opposed by exerting an external pressure on the side containing the salt solution.

In other words, the osmotic pressure is reversed, and this external high pressure working in opposition to nature's low osmotic pressure, forces pure water from the salt solution to move across the membrane towards the side containing water.

## UNIT - V

# WATER DISTRIBUTION AND SUPPLY TO BUILDINGS

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### 5.1 REQUIREMENTS OF A GOOD DISTRIBUTION SYSTEM

- (i) To supply water at sufficient pressure head.
- (ii) To supply requisite quantity of water for fire fighting.
- (iii) Cheap with least capital (construction) cost. The cost of installation of distribution system is about 70% cost of water supply projects.
- (iv) Simple, easy operation and repair. RMO cost and troubles should be minimum.
- (v) Safe against future pollution of water. Water lines should be laid away from drainage and sewerage lines.
- (vi) Safe and should not cause failure of pipelines by bursting.
- (vii) Water should be available even during breakdown periods.
- (viii) Water-tight and leakage losses should be minimum.
- (ix) No obstruction of traffic during repairs.

### 5.2 LAYOUTS OF DISTRIBUTION NETWORKS

The different types of distribution networks are:

1. Dead end system
2. Grid iron system
3. Ring system (circular)
4. Radial system

1. **Dead-end system (Tree system)**

- There is one main supply pipe, from which a number of submain pipes take off at right angles.
- Each submain divides into several branch pipes (Laterals)
- From lateral, service connection are given to consumers.
- Used for older towns with irregular expansion, without properly planned roads.
- Water pipes are randomly laid which leads to formation of number of dead ends.
- As there are no cross connections between the branches, submains and laterals etc. sediment accumulation and water stagnation occurs in the dead ends.

**Advantages :**

- Distribution network can be easily solved. Discharges and Pressures at different points can be easily and accurately calculated.
- Requires lesser number of cut-off valves (sluice valves)
- Shorter pipe lengths are needed and laying of pipes is easier.
- Cheap, simple, can be extended/expanded easily.

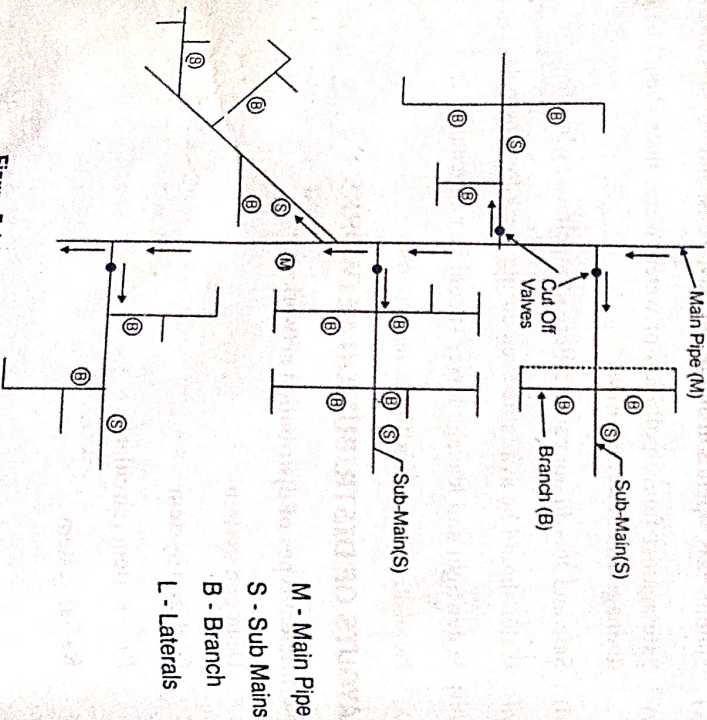


Figure 5.1 Dead End or Tree system

**Disadvantages :**

- Damage or repair in any pipeline completely stops water supply to that area. Greater inconvenience to consumers.
- Numerous dead ends. Stagnation of water leads to degradation of water quality.
- Periodic removal of stale water at dead ends is required by providing scour valves.
- Greater wastage of treated water.
- Supply is only in one direction. Supplies for fire fighting cannot be increased by diverting supplies from other side.

2. **Grid-Iron system / Interlaced / Reticulation system**

- Mains, sub-mains and branches are all inter-connected with each other. In a well-planned city/town, roads are properly developed and the pipelines can follow a grid-iron pattern.
- This system is suitable for well planned cities like Chandigarh.
- There are no dead ends and water remains in continuous circulation.

**Advantages :**

- Since water reaches different places from different routes, the discharge, friction loss, and pipe size are reduced.
- During repairs very small area is affected. Some supply will still reach the area from other route.
- Due to the inter-connections, dead ends are eliminated. Water remains in continuous circulation, which prevents stagnation, pollution and sediment deposits.
- During fire, more water can be diverted towards the affected area by closing the cut off valves.

**Disadvantages :**

- Requires more pipe length and large number of sluice valves (cut off valves).
- Costlier construction
- Design is difficult and costlier. Calculations for determining the pipe size, discharge, velocities and pressures are tedious and may require design experts and computers.

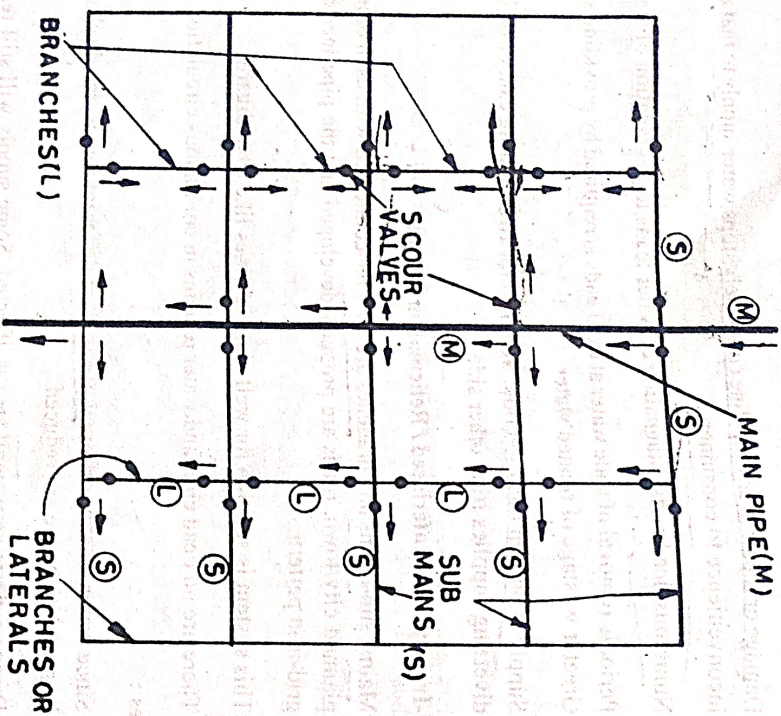


Figure 5.2 Grid - Iron system

### 3. Ring System/ Circular system

- A closed ring either circular or rectangular, of the main pipe is formed around the area to be served. The distribution area is divided into rectangular or circular blocks. The main pipes are laid on the periphery of these blocks.
- Suitable for Towns and Cities having well planned roads.
- Used in combination with grid iron system to increase the capacity and pressures at various points.
- Advantages and Disadvantages of this system are same as grid iron system.

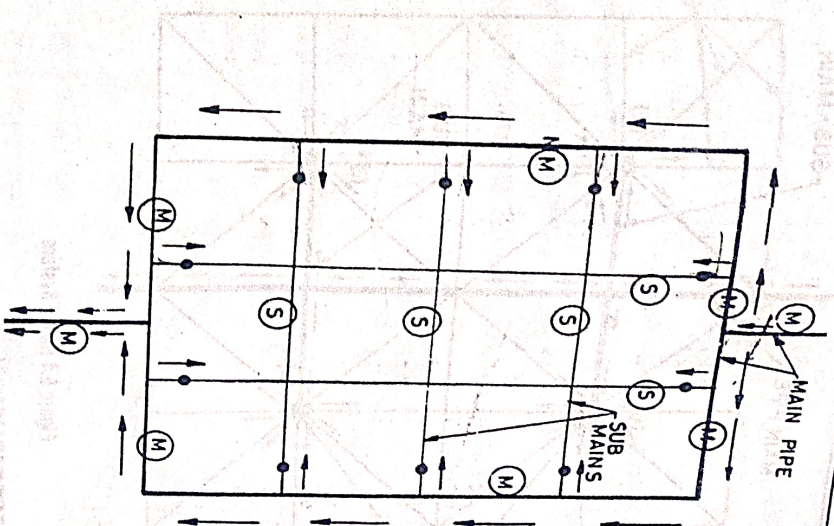


Figure 5.3 Ring System

### 4. Radial system (Reverse of circular)

- Suitable for city or town having radial roads emerging from different centres.
- The distribution reservoirs are placed at these centres.
- Water from the water mains is pumped into the distribution reservoirs placed at different centres. Water is then supplied through radially laid distribution pipes.
- This method ensures high pressures and efficient water distribution.
- The calculations for design of pipe sizes are also simple.

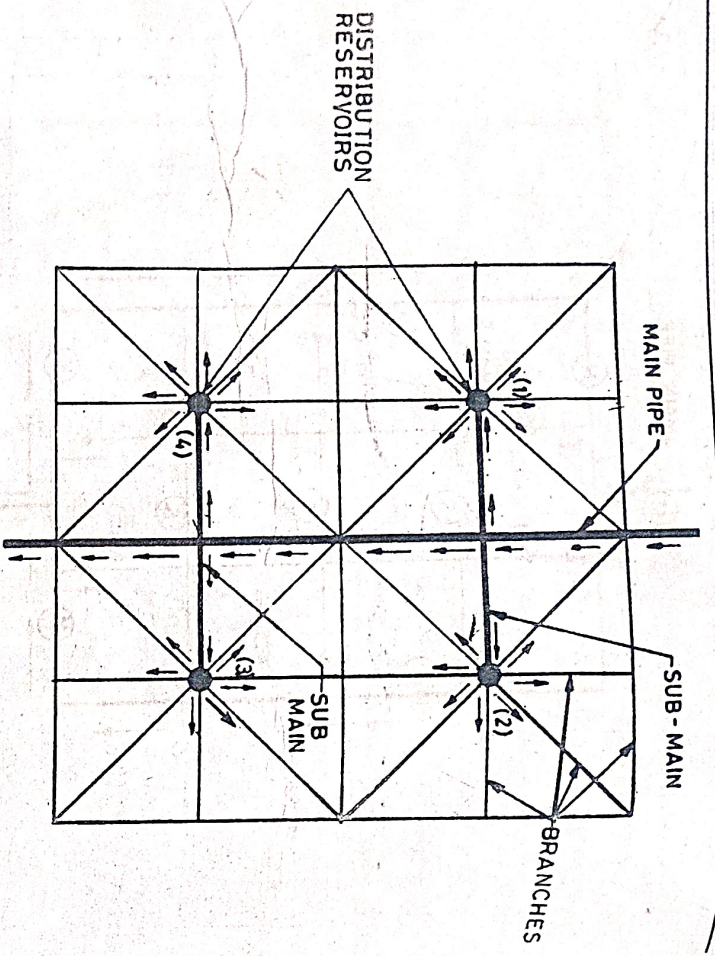


Figure 5.4 Radial System

**5.3. METHODS OF DISTRIBUTION**

- The main objective of distribution system is to develop adequate water pressure at the consumer's taps.
- Depending upon the level of the source and the distribution area, topography of the area and other local conditions; water distribution is done in the following ways:
  1. Gravitational system
  2. Pumping system
  3. Combined gravity and pumping system.

**1. Gravitational system**

- This system is adopted when the source (lakes or reservoirs) are at high level and the distribution area or consumers are at low level.
- Water flows from high level to low level under gravity.
- Economical and reliable system, since no pumping is required.

- Economical and reliable system, since no pumping is required.
- However, sufficient head should be available to maintain adequate pressure at the consumer's end after allowing frictional losses in pipes.
- Suitable for cities located at the foothills.
- Example : Mumbai city is supplied from lakes situated in the hills.
- Leakage and wastages are minimum.
- Size of pipes is reduced for a given discharge.
- Pumping is required only during fires to increase pressure.

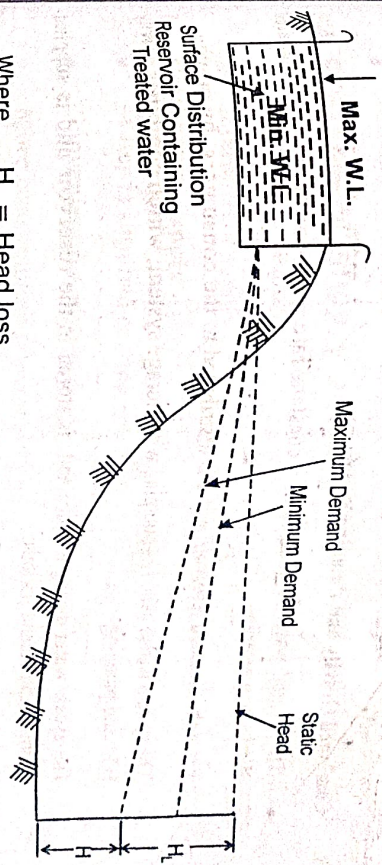


Figure 5.5 Gravitational distribution system

Where  $H_L$  = Head loss

$H$  = Head available to consumers

**2. Pumping System (Pumping without storage system)**

- Treated water (without storage) is directly pumped into the distribution mains.
- High lift pumps are required to be operated at variable speeds to meet the water demand.
- Continuous supervision is required at pumping station.
- During power failures, there will be complete stoppage of supply.
- During fires, large volume of water can be forced at high pressure. But, in case there is a fire during power breakdown, it will be a disaster.

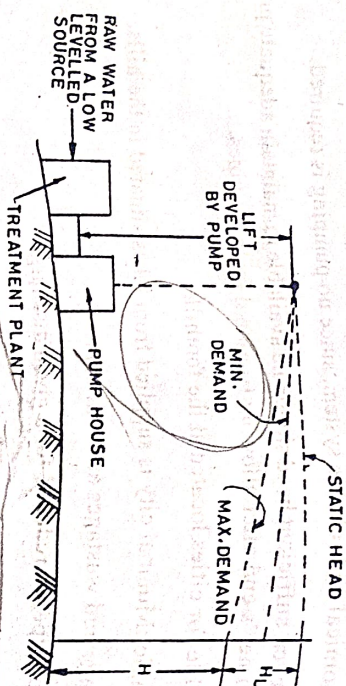


Figure 5.6 Pumping system for water distribution

### 3. Combined Gravity and Pumping System

- The treated water is pumped at a constant rate and stored into an elevated distribution reservoir.
- From the elevated reservoir, water is distributed to the consumers, by gravity.
- The system is also called as pumping with storage system; which combines gravity flow and pumping.
- The excess water during low demands is stored in the reservoir and is supplied during high demand periods.
- The pumps are operated at constant speeds at their rated capacities which increases efficiency and reduces wear and tear. Supervision is also not required.

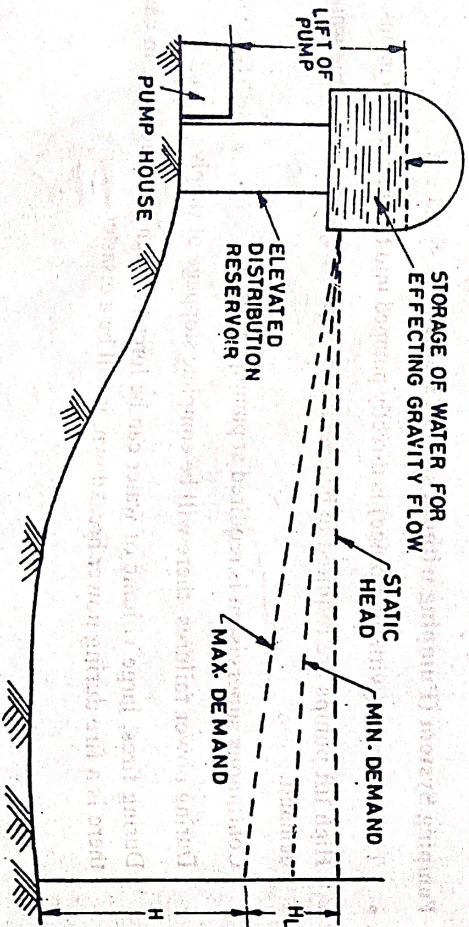


Figure 5.7 Combined Gravity and Pumping System

This system is universally adopted, because of the following advantages :

- The reserve water in the distribution reservoir can be supplied for fire fighting some localities or by using pumps.
- The pumps operate at uniform rate at their rated capacities, which increases their efficiency and reduces wear and tear.
- Supervision is not required for operating the pumps.
- Reliable system. Water can be supplied from storage reservoirs during power or pump failure.
- Cheap, efficient, reliable and universally adopted.

### 5.4 SYSTEMS OF SUPPLY

1. Continuous supply
2. Intermittent supply

#### 1. Continuous supply

- Water is supplied continuously all the 24 hours of the day.
- Convenient for customers.
- More consumption of water by consumers.
- Wasteful use of water.
- Minor leakages in pipe may lead to greater water losses.
- Requires small size distribution pipes, as the supply is continuous.
- Adopted when there is sufficient quantity of water at the source.
- As there is no stagnation of water, water quality is ensured.

#### 2. Intermittent supply

- Water is supplied only during fixed hours (2 to 4 hours) (i.e.) peak periods in the morning or evening.
- Adopted when there is shortage of water at source.

#### Advantages :

- Lesser consumption and saving of water.
- Lesser losses due to leakages.

- High pressure can be achieved.
  - Repair works can be done easily during non supply periods.
- Disadvantages :**

- Greater inconvenience to consumers.
- Fire demand : Fire breakout during non-supply periods may be disastrous.
- Size of pipes : Requires bigger size distribution pipes.
- Domestic storage : Storage tanks are required in individual houses.
- More number of valves are required.
- Staff requirement : Supervision and Staff requirement is more.
- High maintenance cost.
- Wastage from taps : Wastage of water due to negligence i.e. water taps may be left open unknowingly during non-supply periods.
- Pollution in supply : Possibility of water contamination is more through leaky joints.

**5.5 STORAGE AND DISTRIBUTION RESERVOIRS**

**Storage Reservoirs** – store the treated water until it is pumped into the service reservoir or distribution reservoirs.

The capacity of storage reservoirs should be 14 to 16 hours of average daily flow.

- **Distribution Reservoirs** – provide storage to meet the widely fluctuating demands, for fire-fighting and during emergencies.

Distribution Reservoirs serve the following purposes :

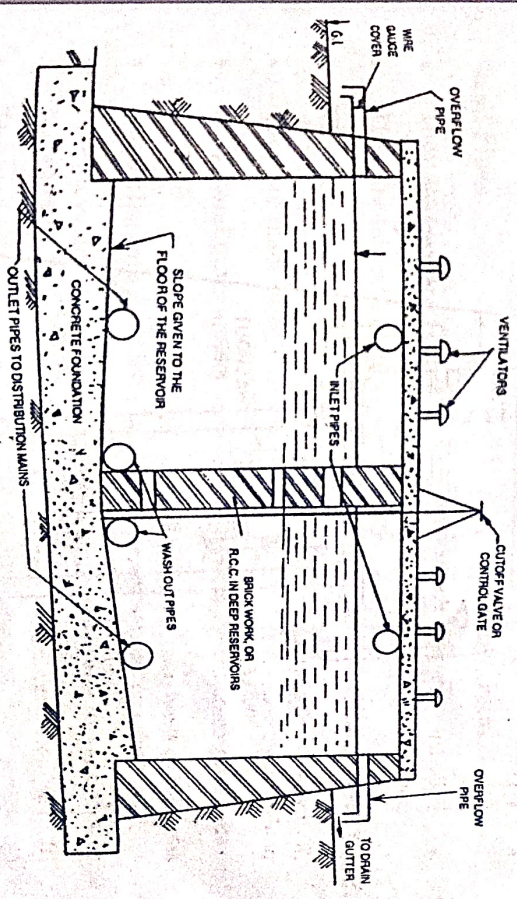
- (i) They absorb the hourly variations in demand.
- (ii) The pumps can be run at constant rate.
- (iii) Reduction in pipe sizes, pumps and treatment units (economical)
- (iv) They serve as storage for emergencies such as fire/ failure of pumps/ bursting mains etc.
- (v) They maintain desired pressure even in remote areas.
- (vi) Operation of distribution system becomes very easy.

**Types of Storage and Distribution Reservoirs :**

1. Surface Reservoirs
2. Elevated Reservoirs
3. Stand Pipes

**Surface Reservoirs (Ground Reservoirs)**

1. Made of masonry or concrete; circular or rectangular; constructed at ground level or below the ground level.
- Lining is provided with concrete or asphalt to check leakage of water.
- They are constructed at high points in the city to achieve gravity flow.
- Sometimes pumps are used to convey water from surface storage reservoirs to elevated distribution reservoirs.



**Figure 5.8 Surface Ground Reservoir**

- The reservoir has two or more compartments to facilitate cleaning and repair.
- The compartments are connected by sluice valves.
- Overflow pipes are provided at full supply level to maintain constant water level.
- Ventilators are provided at roof slab for free circulation of air.
- The sludge settled in the reservoir due to storage of water is removed through washout pipes.

- The cement concrete floor is sloped towards the central washout pipes.
2. **Elevated Reservoirs (Overhead Tanks)**

- Rectangular, circular or elliptical tanks.
- Supported on towers at suitable elevation above ground level.
- Used where pressure requirements are high.
- Used where combined gravity and pumping system of distribution are adopted.
- Water is pumped into these elevated reservoirs from surface reservoirs and then supplied to consumers.
- These tanks are made of RCC, steel, stone masonry or prestressed concrete

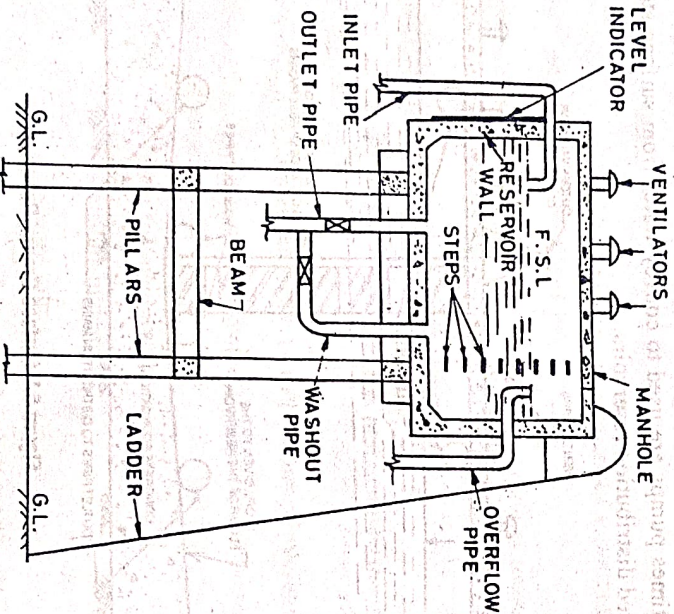


Fig. 5.9 Rectangular Elevated Reservoir

- Steel tanks corrode and have short life.
- Masonry tanks require very heavy supporting towers.
- Hence, RCC overhead tanks are preferred as they are cheaper, do not corrode and requires less maintenance.
- *Intze type RCC tank* is popular due to its structural stability and economy.

- Prestressed concrete elevated tanks are also preferred in modern days, which gives considerable savings in steel and concrete.
- The elevated reservoirs are provided with top roof cover to avoid contamination of water.
- Other accessories of elevated reservoir are:
  - (i) Inlet pipe for entry of water
  - (ii) Outlet pipe for supplying water to distribution mains.
  - (iii) Overflow pipe to maintain constant water level.
  - (iv) Float gauge for indicating depth of water.
  - (v) Wash-out pipe (drain pipe) for removing settled sludge.
  - (vi) Ladders and manholes for cleaning and inspection.
  - (vii) Ventilator for fresh air circulation.

### 1. Stand Pipes

- They are elevated tanks without towers.
- They are tall cylindrical shells resting on ground.
- They are 15 to 30 m high and 10 to 15 m in diameter.
- They are made of RCC or Steel
- RCC stand pipes are not used for heights above 15 m as it cannot bear the high stresses.
- Stand pipes are provided where high heads are required.
- Like elevated reservoirs, stand pipes are also provided with inlet pipe, outlet pipe, wash-out or drain pipe, overflow pipe, manholes, ladders etc.
- The storage volume of the cylindrical tank includes an upper portion (useful storage), which is above the discharge pipe and a lower portion (supporting storage), which supports the useful storage and provides the required head.

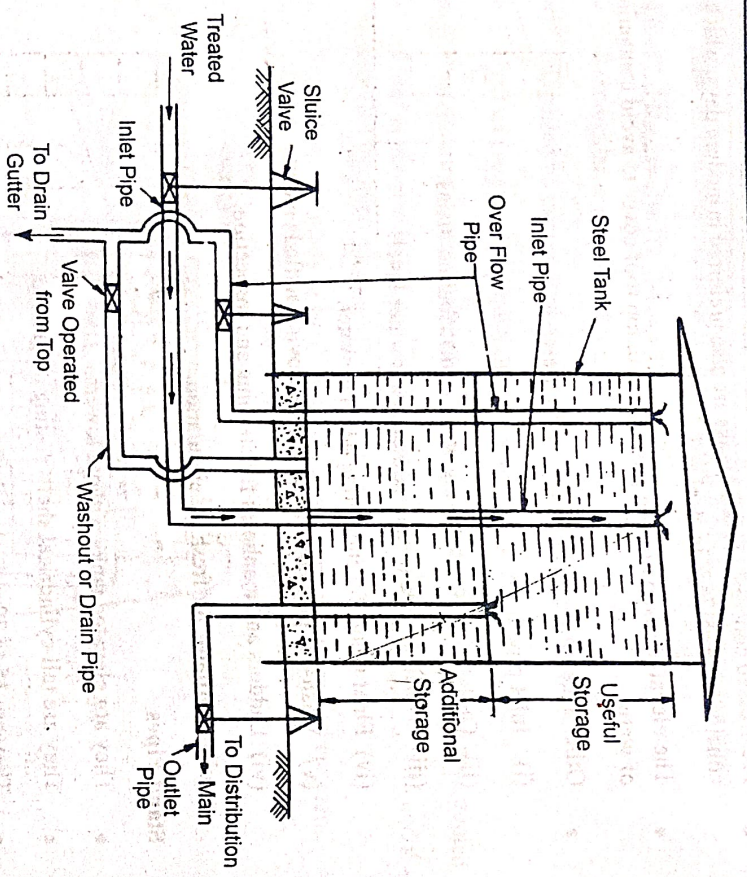


Figure 5.10 Stand Pipes

- The entire capacity of tank can be used during fire-fighting or by locating the stand pipes on hills or high grounds.

**Location of the Distribution Reservoirs**

Following points are considered in deciding the location of distribution reservoir :

- (i) They should be centrally located to have maximum command of the area.
- (ii) They must be near to the area of distribution.
- (iii) They should be located on high grounds/ elevations to maintain adequate pressure.
- (iv) They should be close to the places of heavy demands to reduce the head losses.
- (v) Located so as to reduce the length of pipelines and friction losses.
- (vi) The distribution reservoir may be located in two ways :

- (a) Placed between the pumping station and distribution area.
- (b) Placed at farther end of distribution area.

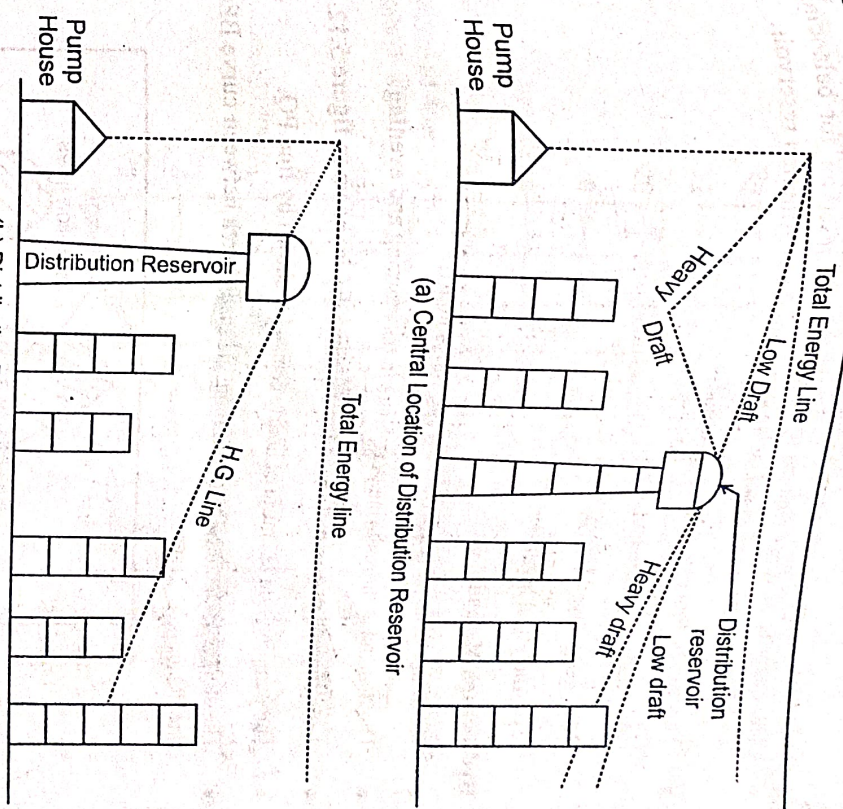


Figure 5.11 Effect of location of Distribution Reservoir

In the former case (a) elevation of reservoir is high, length of pipeline is less and head loss is less.

In the latter case, (b) it is vice versa. However, the total head for pumping will remain the same for both cases.

**5.6 STORAGE CAPACITY OF DISTRIBUTION RESERVOIRS**

The total storage capacity of a distribution reservoir is the total of

1. Balancing storage (or equalising or operating storage)
2. Breakdown storage.
3. Fire storage.

**1. Balancing or Equalising Storage :**

- The primary function of a distribution reservoir is to meet the fluctuating demand.

- The quantity of water required to be stored in the reservoir for balancing the variable demand is called *balancing storage* of the distribution reservoir.
- This can be found by following methods :

- (a) Hydrograph Method.
- (b) Mass curve Method.
- (c) Analytical Methods.

(a) Hydrograph Method :

- The water demand is not constant and varies hourly.
- The demand is more during peak hours in the morning and evening.
- A hydrograph of hourly demand for maximum day is shown in figure 5.12.
- The pumping rate i.e. mean of hourly demand is shown by line PQ.
- The storage is obtained by determining the shaded area between curve BEC and line PQ.

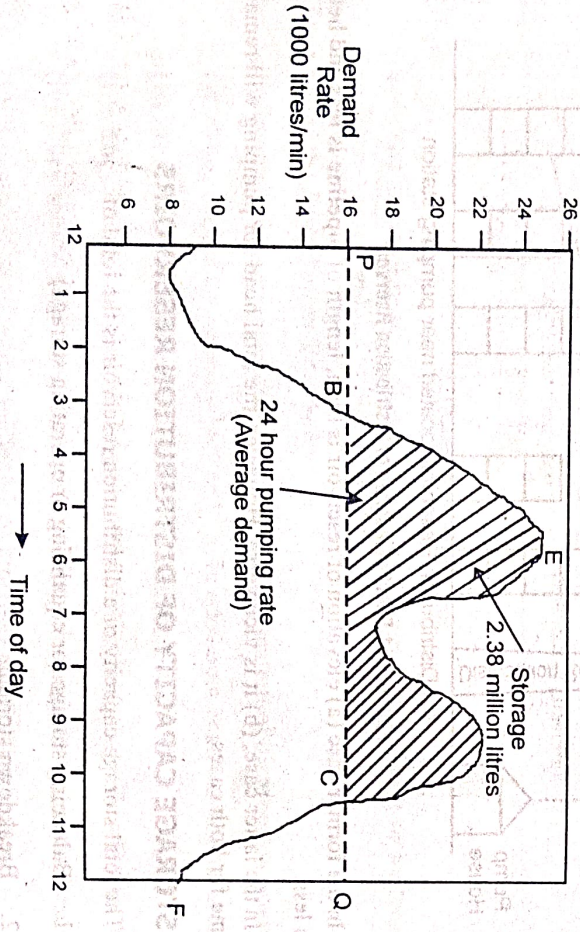


Figure 5.12 Hydrograph Method of Balancing Storage

(b) Mass Curve Method :

A mass curve is the cumulative demand curve which is obtained by continuously adding the hourly demands of the maximum day and plotting against time.

Figure 5.13 shows the mass demand curve CAB plotting it against hours of maximum day.

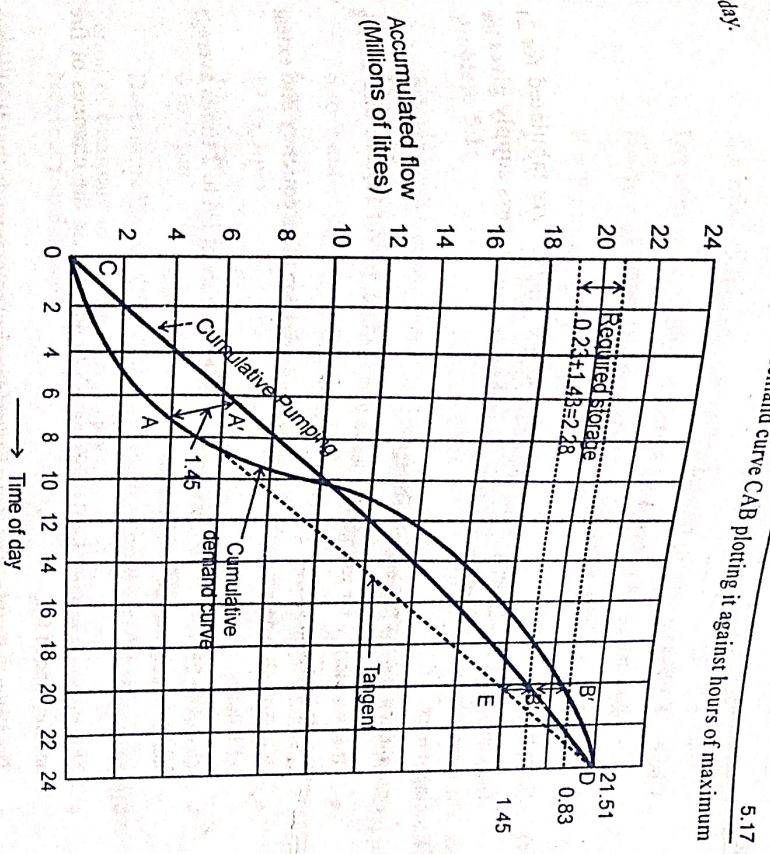


Figure 5.13 Mass curve Method of Balancing Storage

- CAB curve continuously rises.
  - Steepness of curve indicates high rate demand.
  - Flatness of curve indicates low rate demand.
  - Line CD is the cumulative pumping at uniform rate (join ends C&D)
  - Draw tangents through the lowest point A and highest point B parallel to line CD.
  - The highest vertical distance BE between the two tangents = Capacity of balancing storage.
  - At 6 AM there is excess supply = AA' which should be stored.
  - At 8.30 PM there is deficit (BB') which must be drawn from storage
- Therefore, Storage = Morning excess AA' + Evening deficiency BB'

$$S = E_p + E_d$$

Where S = Storage capacity required

$E_p$  = maximum excess supply through pumping

$E_d$  = maximum excess demand (maximum deficiency)

(c) Analytical Method

The cumulative hourly demand and cumulative hourly supplies are tabulated for 24 hrs. The summation of maximum excess demand and the maximum excess supply gives the balancing storage.

2. Breakdown storage (Emergency storage)

- It is the storage for emergencies due to pump failure, power failure and during repair works.
- It is difficult to determine this storage as it depends upon the frequency and extent of failures.
- Generally, 25% of total storage capacity of reservoir or about 1½ to 2 times average hourly supply may be considered as breakdown storage.

3. Fire Storage :

- This storage is required for fire fighting, which depends on the chances of fire and duration of fire.
- *The National Board of Fire Under Writers(America)* recommends that the reserve should supply water for 10 hours for fire fighting in communities of 6000 people and for 8, 6 and 4 hours in places with 4000, 2000 and 1000 people respectively.
- For 10 hours of fire fighting per day, the volume of water required to be stored should be 2 million litres.

Fire reserve is determined from the formula :

$$R = [F - P] T$$

Where, R = reserve storage (litres)

F = fire demand, litres/min

P = reserve fire pumping capacity, litres/min

T = duration of fire, minutes.

McDonand has suggested the following expression

$$R = aD + bD + \frac{10}{24} (D + F - P)$$

Where, R = total storage capacity (million litres)

D = average domestic demand for maximum month (MLD)

F = fire demand (MLD)

P = Pump capacity (MLD)

a, b = Coefficients; 0.2 and 0.1 respectively.

problem 5.1:

A town with a population of one lakh is to be supplied with water daily at 200 litres per head. The variation in demand is as follows

- 6 to 9 am - 40% of total
- 9 am to 12 noon - 10% of total
- 12 to 3 pm - 10% of total
- 3 to 6 pm - 15% of total
- 6 to 9 pm - 25% of total

Determine the capacity of service reservoir assuming pumping at uniform rate and the period of pumping to be from 6 am to 6 pm.

Neglect fire demand.

Solution :

Total daily requirement = 1,00,000 x 200 litres =  $2 \times 10^7$  litres = 20 ML

(a) Analytical Solution

Period	Hours	Rate of demand	Demand in ML	Cumulative demand in ML	Supply at 3 hr	Cumulative supply ML	Excess demand	Excess supply
6 am - 9 am	3	40% of 20 ML	8	8	5	5	3	-
9 am - 12 noon	3	10% of 20 ML	2	10	5	10	-	-
12 noon - 3 pm	3	10% of 20 ML	2	12	5	15	-	3
3 pm - 6 pm	3	15% of 20 ML	3	15	5	20	-	5
6 pm - 9 pm	3	25% of 20 ML	5	20	Nil	20	Max = 3	Max = 5
		$\Sigma = 100\%$	20 ML					

Max. excess demand = 3 ML

Max. excess supply = 5 ML

Total storage = 3 + 5 = 8 ML

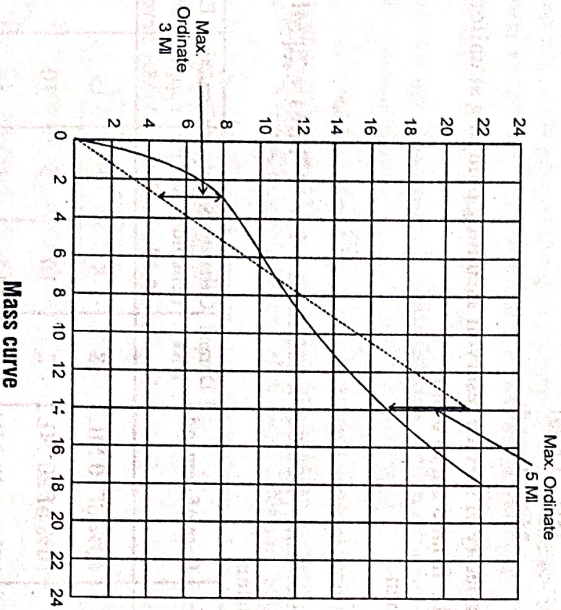
(b) Mass curve method

Graph is plotted between time and cumulative demand.

$$\text{Pumping rate} = \frac{20 \text{ ML}}{12 \text{ hr}} = 1.667 \text{ ML/hr}$$

The supply curve is drawn with slope as 1.667 ML/hr. Maximum ordinates are found between supply and demand lines.

$$\text{Storage} = 3 \text{ ML} + 5 \text{ ML} = 8 \text{ ML}$$



5.7 ANALYSIS OF DISTRIBUTION NETWORK

Conditions to be satisfied in pipe networks:

- The Algebraic sum of pressure drops around a closed loop must be zero. (i.e. no discontinuity in pressure)

Water Distribution and Supply to Buildings

- The flow entering a junction must be equal to the flow leaving the same junction. i.e. law of continuity must be satisfied.

Pipe networks are solved by the following methods:

- (1) Hardy - Cross Method
- (2) Equivalent Pipe Method

1. HARDY-CROSS METHOD

- This method is based on the principle of "Law of Continuity". i.e. at any junction, Inflow = Outflow
  - The flow in each pipe is assumed.
  - A correction to the assumed flow is computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.
- If  $Q_a$  = assumed flow,  $Q$  = actual flow, then correction  $\Delta$  is given by

$$\Delta = Q - Q_a$$

$$Q = Q_a + \Delta$$

Head loss in the pipe is given by

$$H_L = K \cdot Q^n$$

$$= K (Q_a + \Delta)^n$$

$$= K [Q_a^n + n Q_a^{n-1} \Delta + \dots]$$

Negligible terms containing higher powers of  $\Delta$

Around a closed loop, Summation of head losses is zero.

$$\sum K [Q_a^n + n Q_a^{n-1} \Delta] = 0$$

$$\sum K Q_a^n + n \sum K Q_a^{n-1} \Delta = 0$$

$\Delta$  is same for all the pipes of considered loop.

Hence,  $\Delta$  is taken out of summation

$$\sum K Q_a^n = - \Delta \sum K n Q_a^{n-1}$$

$$\Delta = \frac{- \sum K Q_a^n}{\sum K n Q_a^{n-1}} = \frac{- \sum K \cdot Q_a^n}{\sum n \cdot K Q_a^{n-1}} \quad (1)$$

$$\Delta = \frac{-\sum H_L}{x \sum \frac{H_L}{Q_a}} \quad [\because H_L = KQ^x] \quad \dots\dots\dots (2)$$

Where  $H_L$  = head loss for the assumed flow  $Q_a$ .  
 $x$  is constant ;  $x = 1.85$  (for Hazen-William's formula)  
 $x = 2$  (for Darcy-Weisbach formula)

- Algebraic sum of head losses in various pipes in closed loop is computed with assumed flow.
- Correction  $\Delta$  is found for each loop
- Assumed flows in each pipe are corrected.
- Pipes common to two loops will receive both corrections with due attention to sign.

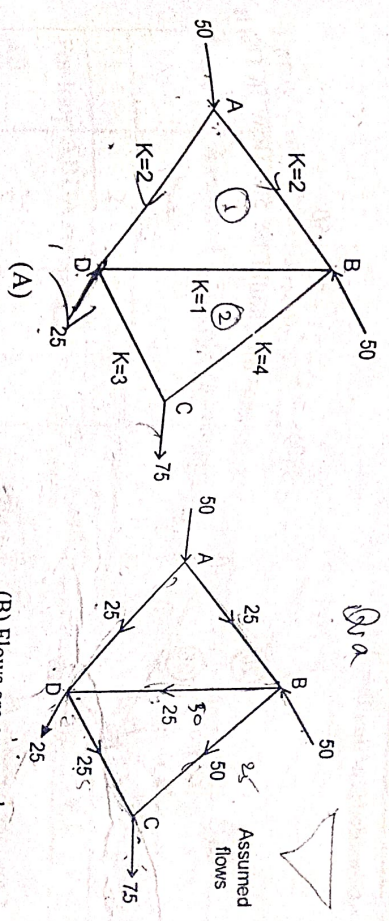
**The Procedure adopted in Hardy Cross method is as follows:**

- The Distribution system is divided into 2 or more loops, such that each pipe in network is included in atleast one loop.
- Assume any internally consistent distribution of flow. The sum of flows entering any junction must be equal to the sum of flows leaving that junction. (INFLOW=OUTFLOW)
- Compute head loss in each pipe by equation or diagram. Conventionally, clockwise flows are positive and vice versa.
- With due attention to sign, compute total head loss around the circuit.  $\sum KQ_a^2$
- Compute without regard to sign, for the circuit, the sum of  $\sum xKQ_a^{x-1}$ .
- Apply corrections obtained from Equation 1 and 2 to the flow in each pipe. Pipes common to two loops will receive both corrections with due regard to sign.

**Problem 5.2:**

Determine the distribution of flow in the pipe network. The Head loss  $H_L$  may be assumed as  $KQ^n$ . The flow is turbulent and pipes are rough. The Value of  $K$  for each pipe is shown in figure. Use Hardy Cross method.

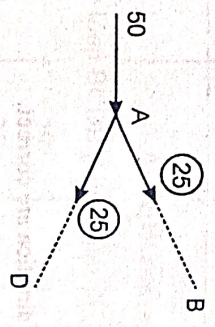
**Solution :**



The Magnitude and directions of possible flows in each pipe are assumed based on the Law of continuity at junction.

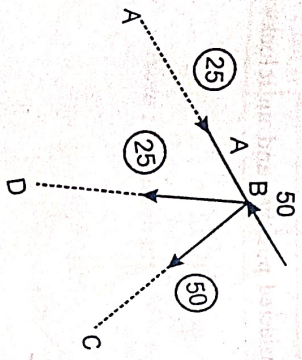
At any junction ; Inflow = Outflow.

**Consider junction A**



Inflow is 50 at A, as it branches out into two pipes; the flow in each pipe AB & AD is assumed as 25.

**Consider junction B**

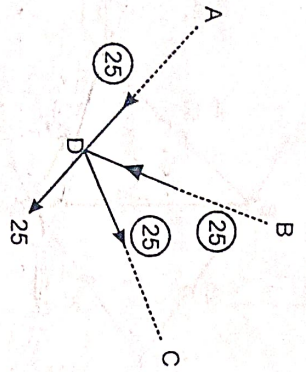


Inflow at B = 50 + 25 = 75

The flow in BC and BD are assumed as 50 and 25; direction away from junction.

Hence, Out flow = 50+25 = 75.

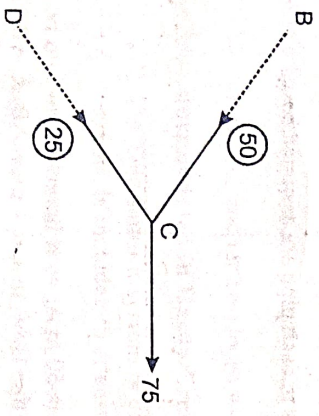
Consider junction D



Inflow at D = 25 + 25 = 50

Since outflow should be 50, flow in DC is assumed as 25.

Consider junction C



Inflow = 50 + 25 = 75

Outflow = 75

Inflow at C = Outflow

- Hence, the flows assumed in magnitude and direction are correct.
- The network is divided into two loops; loop ABDA and loop BCDB. These loops are analysed by Hardy-Cross Method in Table.
- The flow in the clockwise direction is considered positive and anticlockwise direction is negative.

Formula for correction

$$\Delta_1 = \frac{-\sum H_L}{x \sum \left| \frac{H_L}{Q_a} \right|}$$

Assume  $x = 2$  (Darcy-Weisbach formula)

The head loss in each pipe is calculated

$$H_L = KQ^n$$

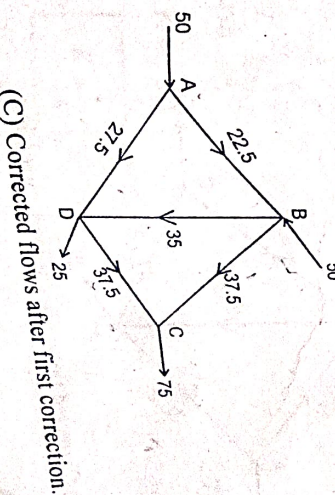
*Handwritten notes:*  
 $n=2$   
 $x=2$

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 Assume  $n = 2$  [Manning's formula or Darcy Weisbach formula, for turbulent flow-rough pipes]  
 $\therefore H_L = KQ^2$

Hardy Cross Procedure for 1st correction

pipe	Assumed flow $Q_a$	K(given)	$H_L = KQ_a^2$	$\left  \frac{H_L}{Q_a} \right $	Corrected Q after first correction $Q_{a1} = Q_a + \Delta_1$ (l/s)
1	2	3	4	5	6
For loop ABDA (loop 1)					
AB	25	2	1250	50	25-2.5 = +22.5
BD	25	1	625	25	25-2.5 + 12.5 = +35.0*
DA	-25	2	(-1250)	50	-25-2.5 = (-27.5)
		$\Sigma$	+625	125	
			$\Delta_1$ for 1st loop = $\frac{-625}{2 \times 125} = -2.5$		
For loop BCDB (loop 2)					
BC	50	4	10000	200	50-12.5 = 37.5
CD	-25	3	(-1875)	75	-25-12.5 = -37.5
DB	-25	1	(-625)	25	-25-12+2.5 = -35.0*
		$\Sigma$	7500	300	
			$\Delta_1$ for 2nd loop = $\frac{-7500}{2 \times 300} = -12.5$		

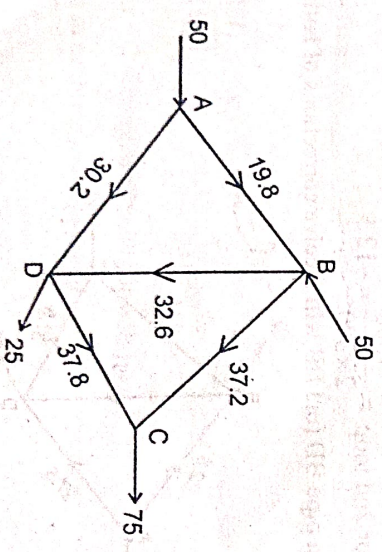
\* Note : Common pipe BD (or) DB will receive corrections of both loops.



(C) Corrected flows after first correction.

Second Correction

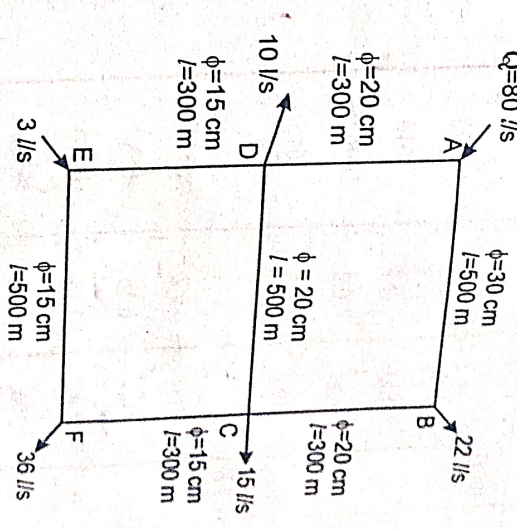
Pipe	Assumed flow $Q_a$ (l/s)	K(given)	$H_L = KQ_a^2$	$\left  \frac{H_L}{Q_a} \right $	Corrected $Q$ after second correction $Q_{a2} = Q_{a1} + \Delta_2$
For loop 1					
AB	22.5	2	1012.5	45	19.8
BD	35.0	1	1225.0	35	32.6*
DA	-27.5	2	-1512.5	55	-30.2
$\Sigma$			725	135	
(For loop 1) $\Delta_2 = \frac{-725}{2 \times 135} = (-)2.7$					
For loop 2					
BC	37.5	4	5625	150	37.2
CD	-37.5	3	-4218.75	112.5	-37.8
DB	-35.0	1	-1225	35	-32.6*
$\Sigma$			181.25	297.5	
(For loop 2) $\Delta_2 = \frac{-181.25}{2 \times 297.5} = -0.3$					



(D) Corrected flows after second correction

Problem 5.3:

Calculate the head losses and the corrected flows in the various pipes of a distribution network shown in figure. The diameters and the lengths of the pipes used are given against each pipe. Make use of Hardy-Cross method with William Hazen's formula. Compute the corrected flows after two corrections.



Solution :

William Hazen's formula

$$H_L = \frac{1}{0.094} \left( \frac{Q}{C_H} \right)^{1.85} \frac{L}{d^{4.87}}$$

Where,  $C_H = 100$  (assumed)

$$H_L = \frac{1}{0.094} \left( \frac{Q_a}{100} \right)^{1.85} \frac{L}{d^{4.87}}$$

$$= \frac{L}{470} \frac{Q_a^{1.85}}{d^{4.87}}$$

$$H_L = K Q_a^{1.85}$$

Where,  $K = \frac{L}{470 d^{4.87}}$

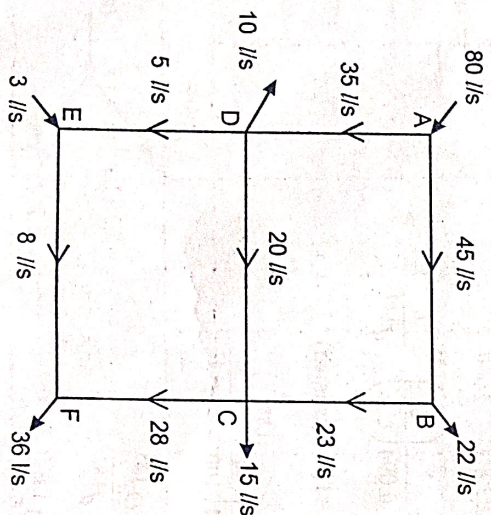
Consider two closed loops; i.e. Loop ABCD and loop DCFE.

Computation of K values for pipes

Pipe	L in m	d in m	$K = \frac{L}{470d^{4.87}}$
<b>Loop ABCD</b>			
AB	500	0.3	373
BC	300	0.2	1615
CD	500	0.2	2690*
DA	300	0.2	1615
<b>Loop DCFE</b>			
DC	500	0.2	2690*
CF	300	0.15	6580
FE	500	0.15	10940
ED	300	0.15	6500

\* Common pipe

Flows are assumed for all the pipes



Hardy Cross Method - First Correction

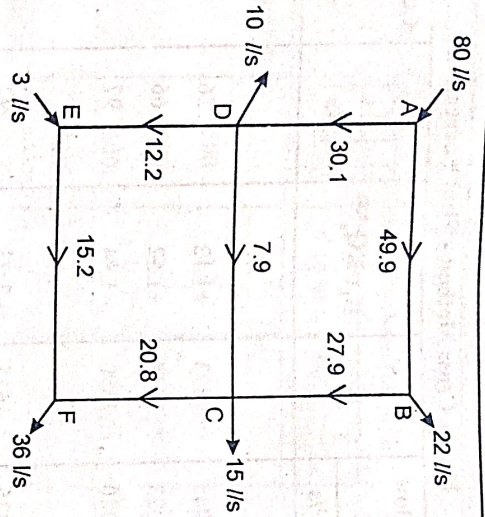
Pipe	Assumed Flow $Q_a$		K	$H_L = KQ_a^{1.85}$	$\left  \frac{H_L}{Q_a} \right $	Corrected flow after first correction $Q_{a1} = Q_a + \Delta_1$
	l/s	m <sup>3</sup> /s				
<b>For loop ABCD</b>						
AB	45	0.045	373	+1.12	26	49.9
BC	23	0.023	1615	+1.52	66	27.9
CD	-20	-0.020	2690	-1.94	97	-7.9*
DA	-35	-0.035	1615	-3.23	92	-30.1
			$\Sigma$	-2.53	281	
<b>For loop DCFE</b>						
DC	20	0.020	2690	+1.94	97	7.9*
CF	28	+0.028	6580	+8.80	314	20.8
FE	-8	-0.008	10940	-1.47	184	-15.2
ED	-5	-0.005	6580	-0.37	74	-12.2
			$\Sigma$	+8.9	669	

$$\Delta_1 = \frac{-\sum H_L}{\sum \frac{H_L}{Q_a}} = \frac{-(-2.53)}{1.85 \times 281} = 4.9 \times 10^{-3} \text{ m}^3/\text{s} = 4.9 \text{ l/s}$$

$$\Delta_1' = \frac{8.9}{1.85 \times 669} = -7.2 \times 10^{-3} \text{ m}^3/\text{s} = -7.2 \text{ l/s}$$

[Note : x = 1.85 → for Hazen Williams formula]

The common pipe CD or DC will receive both the corrections.



Corrected flows after 1st correction

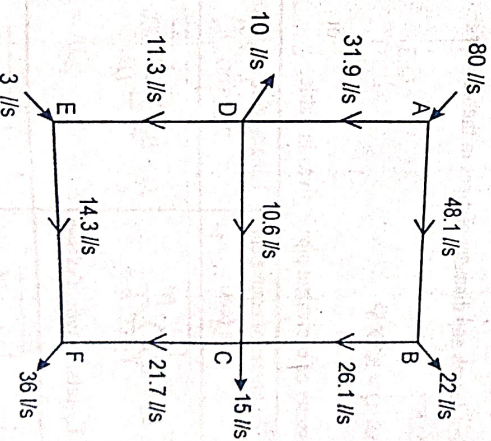
Hardy Cross Method - Second Correction

Pipe	Assumed flow $Q_{a1}$		K	$H_L = KQ_a^{1.85}$	$\frac{H_L}{Q_a}$	Corrected Q after Second correction $Q_{a2} = Q_{a1} + \Delta_2$ (in l/s)
	l/s	m <sup>3</sup> /s				
<b>For loop ABCD</b>						
AB	49.9	0.0499	373	+1.456	29	48.1
BC	27.9	0.0279	1615	+2.150	77	26.1
CD	-7.9	-0.0079	2690	-0.347	44	-10.6*
DA	-30.1	-0.0301	1615	-2.475	82	-31.9
			$\Sigma$	+0.784	232	
<b>For loop DCFE</b>						
DC	7.9	0.0079	2690	+0.347	44	10.6*
CE						
FE						
ED						
			$\Delta_2 = \frac{-0.784}{1.85 \times 232} = -1.8 \times 10^{-3} m^3/s$			
				= 1.8 l/s		

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Pipe	Flow (l/s)	Head Loss (m)	Flow (l/s)	Head Loss (m)
CF	20.8	0.0208	24.5	21.7
FE	-15.2	-0.0152	312	-14.3
ED	-12.2	-0.0122	155	-11.3
$\Sigma$		-1.197	756	
		$\Delta_2 = \frac{-(-1.197)}{1.85 \times 756} = 0.9 \times 10^{-3} m^3/s$		
			= 0.9 l/s	

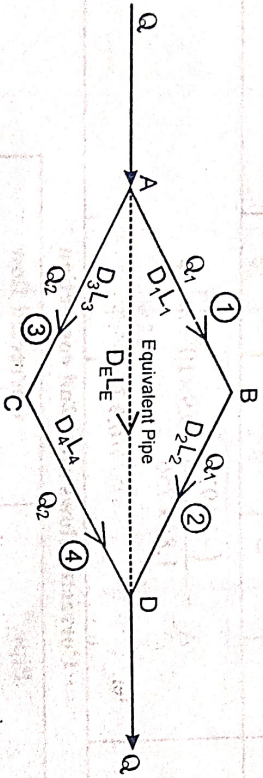
Pipe	Corrected Flow (in l/s)
AB	48.1
AD	31.9
DC	10.6
DE	11.3
EF	14.3
BC	26.1
CF	21.7



Corrected flows after 2nd correction

**2. EQUIVALENT PIPE METHOD:**

- In this method, a complex network of pipes is replaced by a single hydraulically equivalent pipe.
- The equivalent pipe is one which will replace a system of pipes with equal head loss for a given flow.



The two hydraulic principles used in this method are :

- The Head loss through the pipes connected in series (AB-BD) is additive.
- The flows (discharge) through the pipes connected in parallel (ABD-ACD) is distributed such that the head losses are identical.

For solving the pipe network, any head loss formula can be used.

Let  $D_E$  = Diameter of equivalent pipe

$L_E$  = Length of equivalent pipe

$L, D$  = represent length and diameter of pipes in the network

$$hf = \frac{KLQ^n}{D^x} \quad \text{(or)} \quad Q = K D^a S^b$$

The length and diameter of equivalent pipe is given in Table.

System in series	Diameter of equivalent pipe (cm)	Length of equivalent pipe (m)
	$D_E = x \sqrt{L_1 \sum \frac{D^x}{L}}$	$L_E = D_E^x \sum \frac{L}{D^x}$
System in parallel	$D_E = a \sqrt{L_E^b \sum \frac{D^a}{L^b}}$	$L_E = b \sqrt{D_E^a \sum \frac{L^b}{D^a}}$

Note : For Hazen Williams formula  $x = 4.87, a = 2.63, b = 0.54$

For the flow network shown in figure.

$$\text{Head loss } hf = \frac{fLV^2}{2gD} = \frac{16fLQ^2}{2g\pi^2 D^5} = \frac{KLQ^2}{D^5} = \frac{KLQ^n}{D^x}$$

Hence,  $n = 2, x = 5$

**Pipes in Series**

Length of equivalent pipe for pipe AB and BD in series is given by:

Total head loss = summation of individual head loss.

$$\frac{L_E}{D_E^5} = \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5}$$

$$L_E = D_E^5 \left[ \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5} \right]$$

$$L_E = D_E^x \sum \frac{L}{D^x}$$

**Pipes in parallel (pipes ABD and ACD)**

$$h_f(ABD) = h_f(ACD)$$

$$\frac{L_1 Q_1^2}{D_1^5} + \frac{L_2 Q_1^2}{D_2^5} = \frac{L_3 Q_2^2}{D_3^5} + \frac{L_4 Q_2^2}{D_4^5}$$

$$\frac{Q_1}{Q_2} = \sqrt{\frac{\frac{L_3}{D_3^5} + \frac{L_4}{D_4^5}}{\frac{L_1}{D_1^5} + \frac{L_2}{D_2^5}}}$$

$$\text{(or)} \quad Q_1 = A Q_2$$

$$Q = Q_1 + Q_2 = A Q_2 + Q_2 = Q_2(A+1)$$

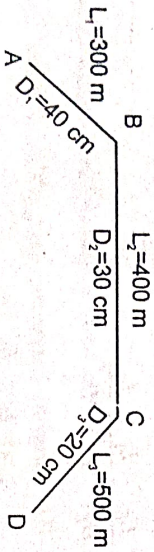
Further,

$$\frac{L_E Q^2}{D_E^5} = \frac{L_3 Q_2^2}{D_3^5} + \frac{L_4 Q_2^2}{D_4^5}$$

$$L_E = \frac{D_E^5}{(A+1)^2} \left[ \frac{L_3}{D_3^5} + \frac{L_4}{D_4^5} \right]$$

**Problem 5.4:**

Find the equivalent length of 30 cm dia pipe for the network shown in figure using (a) Darcy's formula, (b) Hazen Williams formula.



**Solution :**

(a) Darcy's formula

$$h_f = \frac{16fLQ^2}{2g\pi^2 D^5} = \frac{KLQ^2}{D^5}$$

$$L_E = D_E^5 \sum \frac{L}{D^5} = (D_E)^5 \left[ \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5} + \frac{L_3}{D_3^5} \right]$$

$$L_E = (0.3)^5 \left[ \frac{300}{(0.4)^5} + \frac{400}{(0.3)^5} + \frac{500}{(0.2)^5} \right] = 4268 \text{ m}$$

(b) Hazen Williams formula

$$h_f = \frac{KLQ^{1.85}}{D^{4.87}}$$

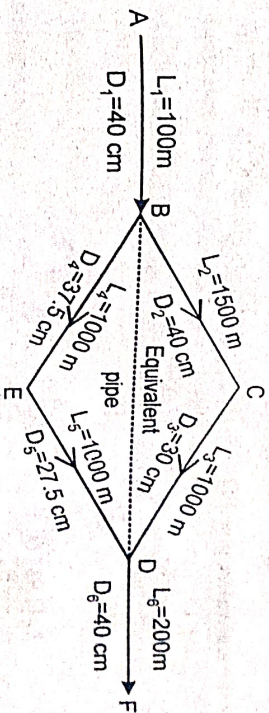
$$\frac{L_E}{D_E^{4.87}} = \sum \frac{L}{D^{4.87}} = \frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}} + \frac{L_3}{D_3^{4.87}}$$

$$L_E = (0.3)^{4.87} \left[ \frac{300}{(0.4)^{4.87}} + \frac{400}{(0.3)^{4.87}} + \frac{500}{(0.2)^{4.87}} \right]$$

$$L_E = 4080.5 \text{ m}$$

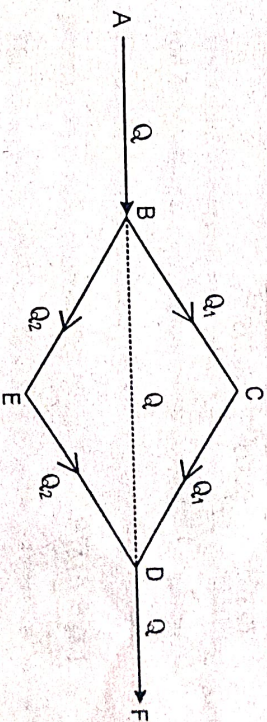
**Problem 5.5 :**

Find the equivalent length of 30 cm dia pipe for the network shown in Figure. Use Hazen Williams formula.



**Solution :**

Using Hazen Williams formula [ $x = 4.87, n = 1.85$ ]



Let the discharge in loop BCD be  $Q_1$  and BED be  $Q_2$

$$Q = Q_1 + Q_2$$

Let  $L_E$  and  $D_E$  be the length and diameter of equivalent pipe BD.

$$h_f(BCD) = h_f(BED)$$

$$\frac{L_2 Q_1^{1.85}}{D_2^{4.87}} + \frac{L_3 Q_1^{1.85}}{D_3^{4.87}} = \frac{L_4 Q_2^{1.85}}{D_4^{4.87}} + \frac{L_5 Q_2^{1.85}}{D_5^{4.87}}$$

$$\left( \frac{Q_1}{Q_2} \right)^{1.85} = \left[ \frac{\frac{L_4}{D_4^{4.87}} + \frac{L_5}{D_5^{4.87}}}{\frac{L_2}{D_2^{4.87}} + \frac{L_3}{D_3^{4.87}}} \right]$$

$$Q_1 = 0.987 Q_2$$

$$\text{Now, } Q = Q_1 + Q_2$$

$$Q = 0.987 Q_2 + Q_2 = 1.987 Q_2$$

(a) For the equivalent pipe BD,

$$\frac{L_E Q^{1.85}}{D_E^{4.87}} = \frac{L_4 Q_2^{1.85}}{D_4^{4.87}} + \frac{L_5 Q_2^{1.85}}{D_5^{4.87}}$$

$$\frac{L_E (1.987 Q)^{1.85}}{D_E^{4.87}} = \frac{L_4 Q_2^{1.85}}{D_4^{4.87}} + \frac{L_5 Q_2^{1.85}}{D_5^{4.87}}$$

$$\frac{L_E (1.987)^{1.85}}{(0.3)^{4.87}} = \frac{1000}{(0.375)^{4.87}} + \frac{1000}{(0.275)^{4.87}}$$

$$L_E = 375.5 \text{ m}$$

(b) Equivalent length for AB,

$$\frac{L_E Q^{1.85}}{D_E^{4.87}} = \frac{L_1 Q^{1.85}}{D_1^{4.87}}$$

$$L_E = \left( \frac{D_E}{D_1} \right)^{4.87} L_1 = \left( \frac{0.3}{0.4} \right)^{4.87} \times 100 = 24.6 \text{ m}$$

(c) Equivalent length for DF,

$$L_E = \left( \frac{D_E}{D_6} \right)^{4.87} L_6 = \left( \frac{0.3}{0.4} \right)^{4.87} \times 200 = 49.2 \text{ m}$$

∴ Total equivalent length

$$= 24.6 + 375.5 + 49.2$$

$$= 449.3 \text{ m}$$

Leakage detection methods :

- (i) by direct observation
- (ii) by using sounding rods
- (iii) by plotting hydraulic gradient line
- (iv) by using waste detection meters.

1. By direct observations :

- Wet soft spots on unpaved ground, grasses, emergence of springs at odd places indicates leakage from underground pipes.
- Such indications will be available when pipes are laid below loamy or clayey soils.
- However, direct observation is difficult in sandy soils.

2. By using sounding rods :

- A sharp pointed metal rod is thrust into the ground along the pipe line and pulled up for inspection.
- Its moist or muddy point indicates leakage.
- The sound of escaping water can be heard by placing the ear on top of the inserted rod or by using magnifying instruments –aquaphone or sonoscope.
- The sound hearing should be done during night hours.

3. By plotting hydraulic gradient line

- The pressures at various points along a suspected pipeline are measured and the HGL is plotted.
- Any kink or change in slope of the HGL will indicate the location of leakage.

4. By using waste detection meters

- These meters measure the unusually high flows passing through the water mains during periods of low consumption (during night or early morning)
- The unusual flow indicates leakage.
- This test is conducted during night hours.

**Method :** The suspected locality is isolated.

- The supplies to all other areas are closed down except the suspected area.

- The meter is fitted at the head of main supply pipe and flow is recorded.
- The laterals and branches of the locality are progressively shut off.
- The shut off that indicates a large disproportionate drop in flow indicates leakage.
- Steps are taken to rectify the defects.

*Deacon's water detection meters* are widely used as they are sensitive and accurate. The water passing through the meter forces down a brass disc which moves a pencil point up and down on a graph paper mounted on a drum. It automatically records the discharge of water.

## 5.9 APPURTENANCES IN DISTRIBUTION SYSTEM

The following appurtenances are required for the efficient functioning of the distribution network.

1. Valves
  - (i) Sluice valves (or) Gate valves
  - (ii) Check valves
  - (iii) Air valves
  - (iv) Drain or scour valves

[Valves have been discussed in Chapter 2]

2. Fire hydrants
3. Water Meters
4. Water Taps
5. Stop Cocks
6. Pipe Bends etc.

### 2. Fire hydrants

- A fire hydrant is an outlet provided in a distribution main or sub main (i.e. pipe of 15 cm  $\phi$ ) for tapping water during fire and sometimes used for filling the municipal water tankers.
- They are provided at street crossings or turnings at 90 to 120m interval.
- During fire outbreaks, the fire hydrant is connected to a fire hose or fire engine to discharge large quantity of water at high pressure.

- Such high pressures are developed by attaching the fire hydrant to the fire engine.
- The fire engine boosts the water pressure within the engine.
- The high pressure water is then discharged out through the hose pipe attached to the outlet of fire engine.
- The pressure developed is atleast 32 m water head.

Water Pressures at the fire hydrants should be :

- (i) Using Motor pumps – 7 to 14 m head of water
- (ii) Direct flow from fire hydrant – 35 to 50 m head of water

Requirements of good hydrant are :

- Easy to connect hose or motor pump
- Cheap
- Easily detectable during fire
- Provide undisturbed water flow
- Not get out of order during operation.

Types of fire hydrants :

### (i) Flush fire hydrant

Installed underground in brick or CI chamber with top cover above the street level. They are less prone to damage. But they are not easily detectable during fire. This type of hydrant is widely used in India.

### (ii) Post fire hydrant

Its like post standing 0.9 to 1.2 m above ground and can be easily detected but is liable to damage.

- It consists of a barrel of cast iron, connected to water mains.
- A valve stem; with leather valve at lower end and handle on upper end is provided, to regulate the flow. When closed; leather valve rests against the valve seat.

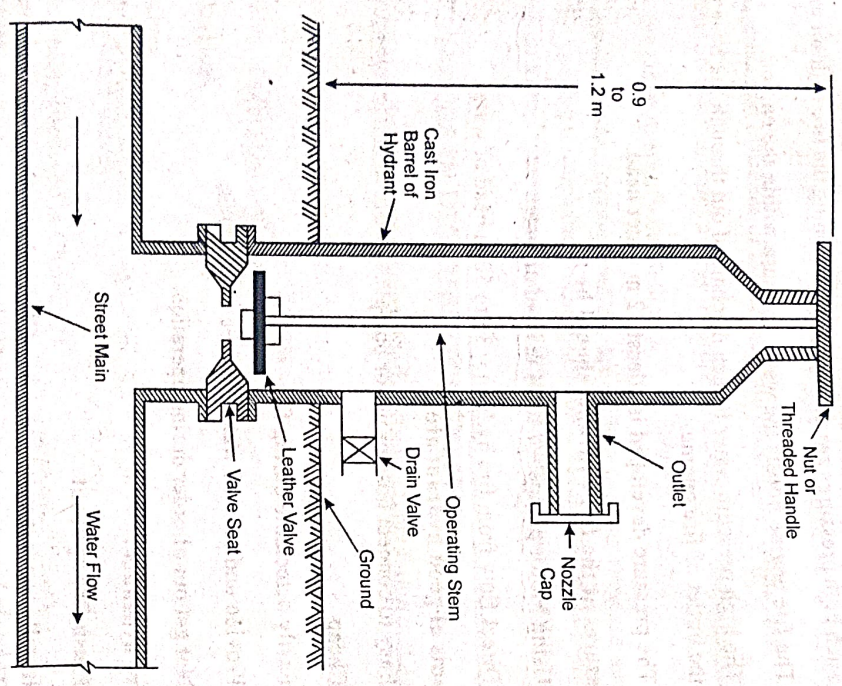


Figure 5.14 Post Fire Hydrant

- For opening the hydrant, the Nut/ handle is rotated so as to raise leather valve thereby allowing water inside the barrel.
- Based on the number of outlet openings, they are classified as *one-way, two-way, three-way or four-way hydrants*.
- Usually 2 outlets are provided. One connected to hose, when pressure boosting is not required. Other connected to fire engine or pumps; when boosting is required.

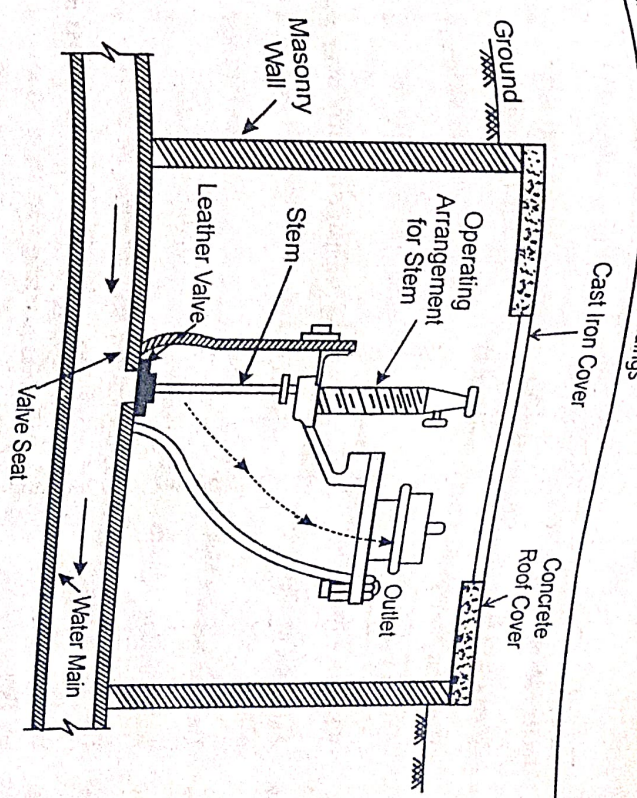


Figure 5.15 Flush Fire Hydrant

3. Water Meters

Measures the quantity of water flowing under pressure through pressure conduits in order to charge the consumers.

Requirements of good water meter:

- It should Record all discharges
- Maintenance and repair should be easy
- Minimum error in measuring discharges (less than 20%)
- Work efficiently at all pressures
- Minimum hindrance to flow (Min. head loss)
- Parts should not be damaged by chemicals present in water
- Prevent backflow and should not be liable to clogging.

Types :

- Velocity/Inferential Meters
- Positive/Displacement Meters

## (i) Velocity / Inferential meters

- It measures horizontal flow velocity (V)
- Discharge through the meter is computed by

$$Q = A \times V$$

Where, A = Area of flow cross - section

- Automatic arrangements are made to record the discharge directly over a period of time
- They can measure high flows
- Widely used in Industries / Trade
- They can be used for measuring raw and sedimented water.
- They are not used for small domestic supplies, as their accuracy is less during low flows.

## Types of Velocity Meters:

- Rotary meters
  - Turbine meters
  - Venturi meters
- a) Rotary meter

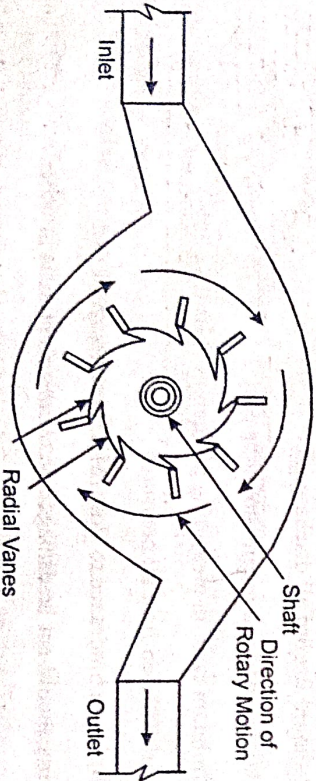


Figure 5.16 Rotary meter (velocity meter)

- Consists of radial vanes attached to a shaft, enclosed in a casing.
- When water passes through the meter, radial vanes are rotated in clockwise direction, which revolve the shaft.
- The number of revolutions per unit time depends on flow velocity.

## Water Distribution and Supply to Buildings

- The velocity of flow and discharge is proportional to speed of shaft.
- The meter is calibrated to directly read the discharge or the total discharge over a period of time.

5.43

## b) Turbine meter

- Similar to rotary meter
- Consists of a rotary turbine wheel which is rotated by moving water.
- The number of revolutions made by turbine wheel gives the discharge.

## c) Venturi meter

- Follows the Bernoulli's principle.
- Used for raw water and measuring high flows in large pipes with minimum head loss. It is not suitable for low flows.
- It consists of a gradually contracting pipe with a throat section and an expanding pipe section.

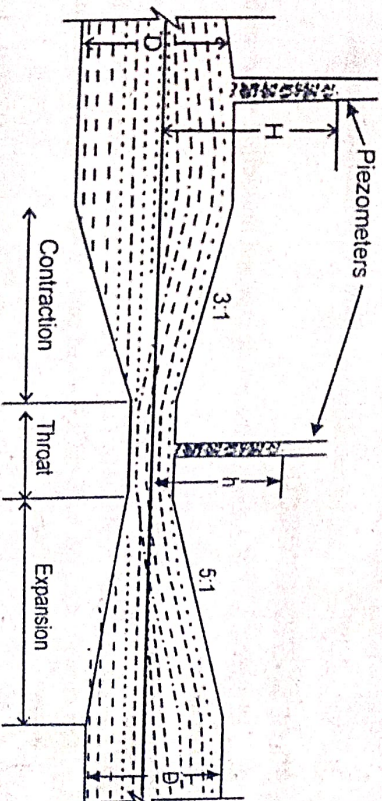


Figure 5.17 Venturi Meter (Velocity Meter)

- Piezometers are inserted at normal end and throat and the levels are noted.
- The Discharge through the pipe is proportional to the difference of head between two piezometers.

## Advantage and Disadvantage of velocity meters over positive displacement meters:

- Cheaper, light and require lesser head.
- Less accurate
- Installed only on horizontal pipes.

## (ii) Positive or displacement meters

- More accurate and they measure the quantity of passing water by counting the number of times the meter chamber is filled and emptied.
- Quantity of flow over a given period of time = Capacity of meter chamber  $\times$  number of times of filling and emptying.

Types:

- Reciprocating type
- Oscillating type
- Disc type (common)

- The **Disc type** meter consists of a disc placed inside a chamber provided with inlet and outlet.
- When water enters the chamber, the disc oscillates with a spiral motion.
- One revolution means one complete filling and emptying of chamber.
- The discharge is recorded automatically by the revolution of gears.
- This meter is widely used for measuring small flows in residential houses.

**5.10 HOUSE SERVICE CONNECTION**

A typical water connection, connecting the service pipe and municipal water main is shown in figure.

The water connection consists of :

- Ferrule** – It is a right angle sleeve made of brass or gun metal and is joined to a hole drilled in the water main and is screwed down with a plug. Its size varies between 10 to 50 mm dia.
- Goose neck** – A small size curve pipe made of flexible material usually lead, about 75cm length forming a flexible connection between the water main and the service pipe.
- Service pipe** – Galvanised iron pipe < 50mm dia laid underground in a trench. The service pipe is connected to the municipal main through the goose neck and ferrule.

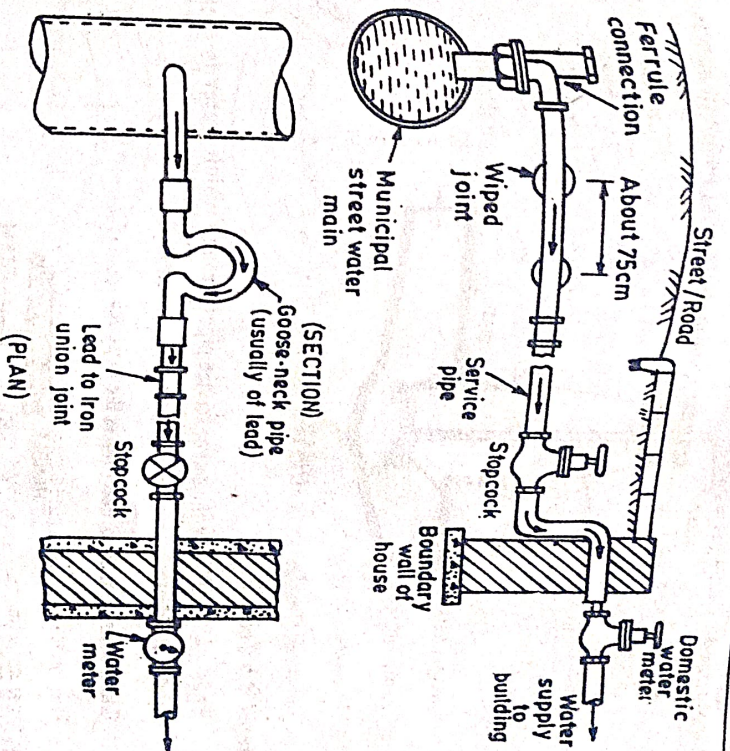


Figure 5.18 The Water Connection

- Stop cock** – Provided before the water meter in the house. It is housed in a masonry chamber with removable cover and fixed in the street close to the boundary wall.
- Water meter** – Measures/ records the quantity of water consumed in the house. It is connected to service pipes by union joint. It is fixed inside iron box fitted in cavity made in boundary wall of house and covered with movable iron cover.

**Stop cocks**

- It is a screw down type sluice valve fitted in small sized (< 50mm) pipes for opening or stopping the supply.
- They are provided at the water entrance of each building or within the building.
- They should be enclosed in cast iron box having a hinged cover. Water passes through an orifice when the valve is raised. When the valve is closed, it rests on the seat, thereby closing the orifice.

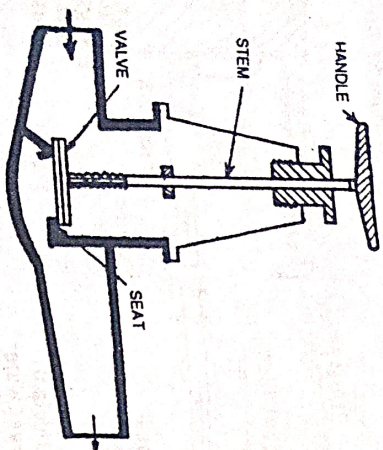


Figure 5.19 Stop Cock

**Water taps/ Bib Cocks :**

- They are provided at the end of service pipes through which water is withdrawn by the consumers.
- The common type of water tap is the Bib cock.

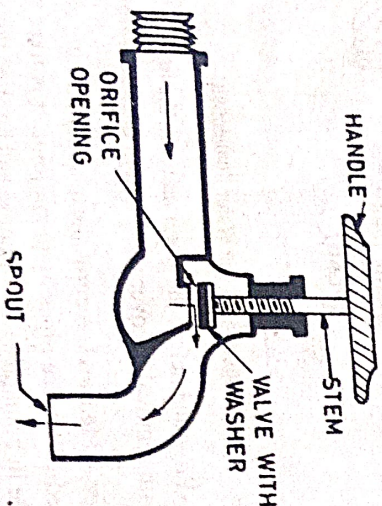


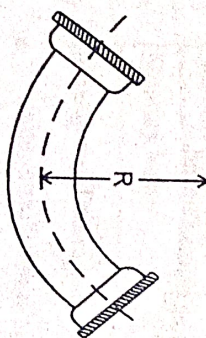
Figure 5.20 Bib cock / Water Taps

- By rotating the handle, the orifice opens and water passes out through the spout.
- They can be fitted in pipe size from 10 to 15mm dia.
- Bib cocks may also be of push type. It opens with a slight push vertically up ward and closes down automatically under self weight.
- Bib cocks should be water-tight and should not leak.
- The rubber or leather washers used in them should be replaced as and when needed.

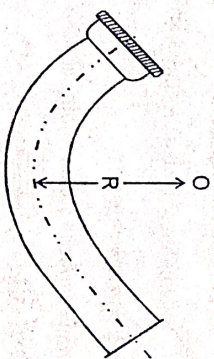
**Water Distribution and Supply to Buildings**  
**Pipe fittings :**

Fittings are used in making service connections.

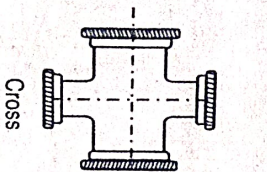
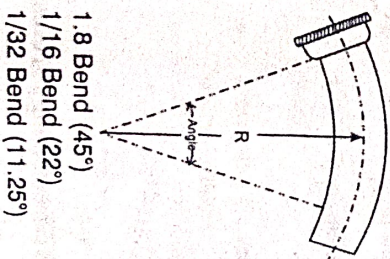
- Bends
- Tees
- Unions
- Plugs
- Nipples etc.
- Crosses
- Elbows
- Caps
- Flanges



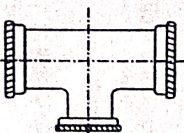
1/4 Bend with double hub



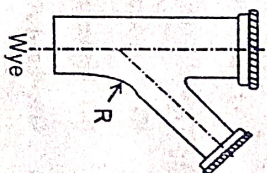
1/4 Bend with single hub



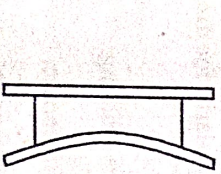
Cross



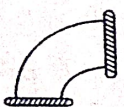
Tee



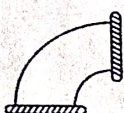
Wye



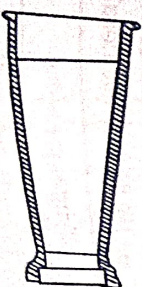
Saddle flange



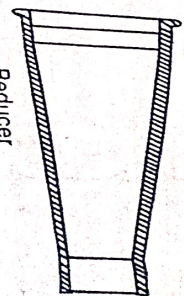
Reducing elbow or bend



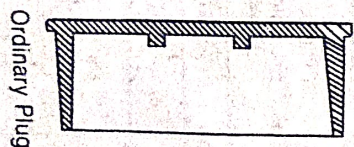
Elbow or bend



Increaser



Reducer



Ordinary Plug

Figure 5.21 Varou pipe fittings

### 5.1.1 PRINCIPLES OF DESIGN OF WATER SUPPLY IN BUILDINGS

#### Storage of Water in Buildings :

Storage of water within the building is necessary because of the following reasons :

- Storage of water within the building is necessary because of the following reasons :
- Municipal supplies are not available round the clock.
- To meet fire demand.
- To provide uninterrupted water supply during power failure or repairs.
- To supplement the direct municipal supply during excess demand.

#### Estimating storage capacity :

Storage capacity for a building depends on :

- (i) Hours of supply
- (ii) Rate of supply or pressure in mains.
- (iii) Demand pattern in the building
- (iv) Fire storage required.

Two types of water storages are required in buildings :

- (i) Overhead storage
- (ii) Underground storage

- In India, the water supply is intermittent i.e. for few hours in the morning and evening.
- It is therefore necessary to store water in overhead tanks particularly for use in toilets and urinals.
- The storage depends upon the number of sanitary fixtures in the building.
- It varies from city to city depending upon the living standards of people.

Table 5.1: Water storage required for flushing in Buildings

S.No.	Types of Building	Storage capacity required
1	For residences	270 litres for one W.C and 180 litres for additional se.
2	For factories & workshops	900 litres per W.C and 180 litres per urinal
3.	For Cinema or Public halls	900 litres per W.C and 350 litres per urinal.

Table 5.2: Storage required for Domestic uses

S.No.	Types of Building	Unit storage in litres per unit	Unit
1.	Dwelling units		
1.	Hostels	70	Resident
2	Hostels	90	Resident
3	Hotels	135	Resident
4	Commercial Buildings	45	Head
5	Schools	25	Head
6	Nursing homes	135	Resident

#### (ii) Underground Storage :

- Underground storage tanks are required to collect water from municipal supply lines, if the water pressure is insufficient to reach the overhead tanks.
- The collected water from underground tank is pumped upto overhead tank.
- Capacity of underground storage = Daily peak demand – flow during the supply hours.
- Normally, the underground storage is considered as 12 to 24 hours of average daily demand.

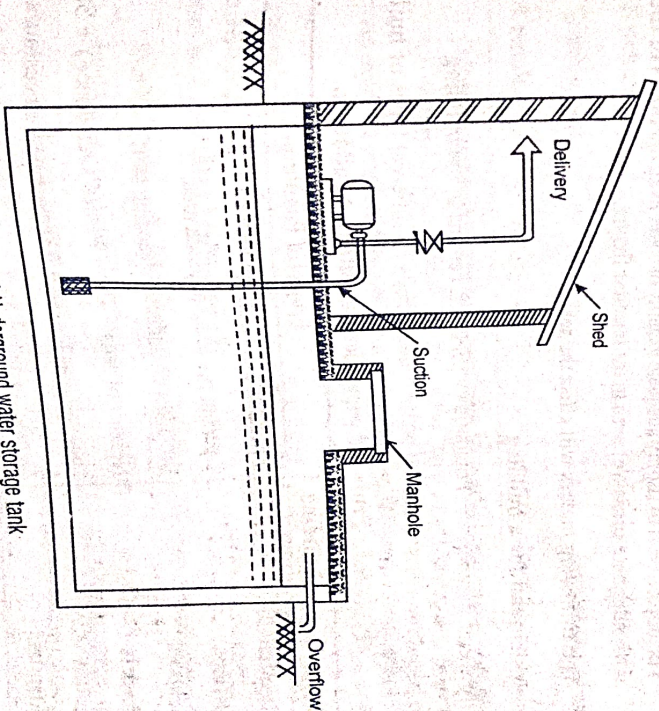


Figure 5.22 Underground water storage tank

**General requirements of domestic water storage tanks :**

- (i) Water tanks should be water-tight and constructed with non-corrosive and non-toxic materials.
- (ii) Sufficient number of manholes and corrosion resistant steps should be provided for maintenance.
- (iii) Vent pipes should be provided for ventilation and to prevent negative pressures.
- (iv) Overflow pipes should be provided to indicate overflow of water in the tank.
- (v) Bottom scour pipes should be provided to empty the tank easily.
- (vi) There should not be any direct connections to any drain, gully trap or sewer.
- (vii) Underground tanks should not be located in low-lying areas to prevent entry of surface runoff or subsoil water.
- (viii) Tanks should not be located near sewers, septic tanks, soak pits etc.
- (ix) The top slab cover of underground tanks should be able to withstand traffic loads.
- (x) The retaining walls of underground tanks should be structurally safe to withstand the earth pressure.

**Design considerations for water piping systems in buildings :**

- The objective is to supply adequate quantity of water to all the floors of the building with adequate pressure; even to the remotest fixture.
- The following factors will affect the design.

**1. Water demand for a building**

Daily water demand = Population  $\times$  per capita demand of the building

The population is worked out on the following basis for different types of buildings.

**Table 5.3 : Projected populations for different buildings.**

Sl.No.	Type/ Use of building	Projected Population
1	Residence	5 persons per dwelling unit area
2	Offices	1 person per 10 m <sup>2</sup> of plinth area.
3	Schools	Strengths of students + teaching staff
4	Hostels	Number of beds + 4.5 $\times$ (Warden's residence) + Staff
5	Hotels	Number of beds + Staff + Requirement of restaurant seats
6	Hospitals	Number of beds + Staff

Note : 5 to 15% additional population for visitors.

**2. Required flows for various water supply fixtures and probable simultaneous demand.**

- Adequate pressure should be made available even at the remotest fixture in the building.
- In a house, fixtures like W.C., Wash basin, bath tub will not be operated simultaneously at a time.
- Each fixture will require different flow rates. But only one fixture can be used at a time.
- It is therefore sufficient to design the gross supply rate for the fixture that require the highest rate of flow.

**Table 5.4 : Flow Rates and Fixture Units for various fixtures.**

S.No.	Type of fixture	Required flow rate in l/s	Fixture Unit
1	Ablution tap	0.12	1
2	Bath tubs	0.2	4
3	Showers	0.15	2
4	Wash basins	0.12	1
5	Kitchen Sinks	0.15	2
6	Water closet	1.5	8
7	Urinals	1	6

- Gross demand of a building is computed, by multiplying number of flats in the building with the required flow rate of the fixture having highest flow rate.

Gross demand of a building = Number of flats in the building  $\times$  flow rate of fixture (having highest flow rate)

**Example :** In a building with a water closet, bath tub, kitchen sink, wash basin and ablution tap, the gross demand will be taken as 0.20 l/s which corresponds to the bath tub (maximum rate among the 5 fixtures)

- Similarly, the probability of using any fixture simultaneously in all the flats of the building is also quite remote.
- If pipe sizes are designed assuming that all the fixtures in the building are open, it would lead to large size pipes that would be unnecessary and uneconomical.

- Hence, the probability of simultaneous demand has to be calculated by statistical methods, which is tedious.
- A simple method "Fretwel's formula" gives the probable simultaneous demand as:

$$n = \sqrt{N}$$

where,  $n$  = probable number of fixtures likely to be open at the same time.

$N$  = total number of fixtures.

3. Design Methods and Principles :

- Simple tables and graphs are available to calculate the probable flow rate of fixtures or demand of the building.
- Pipe sizes are calculated using following data :
  - ❖ Rate of flow
  - ❖ Loading units
  - ❖ Simultaneous demand
  - ❖ Frictional loss in pipes
  - ❖ Taps and fittings

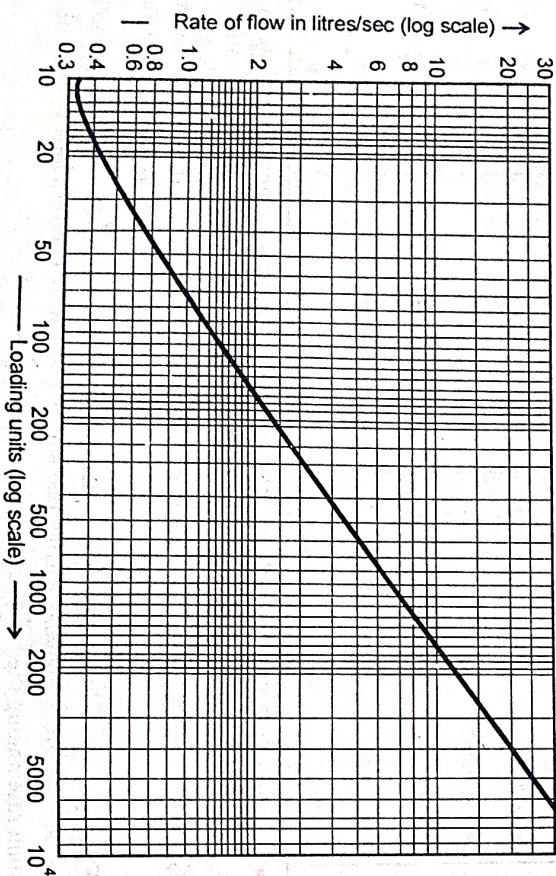


Figure 5.23 Probable simultaneous demand

- Pipe length can be estimated by drawing an isometric view showing the pipe runs marked to scale. The total developed length of the pipeline starting from its source to all supply points, and the number of fittings eg.: bends, tees and elbows etc. can be worked out.

- When water is supplied from overhead tanks or pumping system, the fixtures on the top floors will have least pressure and likely to be deficient in water supply. It is achieved by adding the frictional loss of the branch lines to that of the main vertical line.
- As the pressure is higher in lower floors, pipe diameters are reduced successively to increase the frictional loss to balance the flow.
- In very tall buildings, it is better to divide the building in vertical hydraulic zones. The supply to each zone may be given from a separate tank. e.g. For a 16-storeyed building; water tank installed on the 8th floor may supply for lower 8 storeys and another water tank installed on the terrace will supply for the upper 8 storeys.
- In tall buildings, pressure reducing valves must be used for supply to the lower floors.
- Excessive pressure in pipes may cause wastage of water, leakage in fittings, noise due to water hammer and wear and tear of tap. Hence pressure inhibitors may be provided on water taps to maintain constant flow rate irrespective of the pressure at tap.

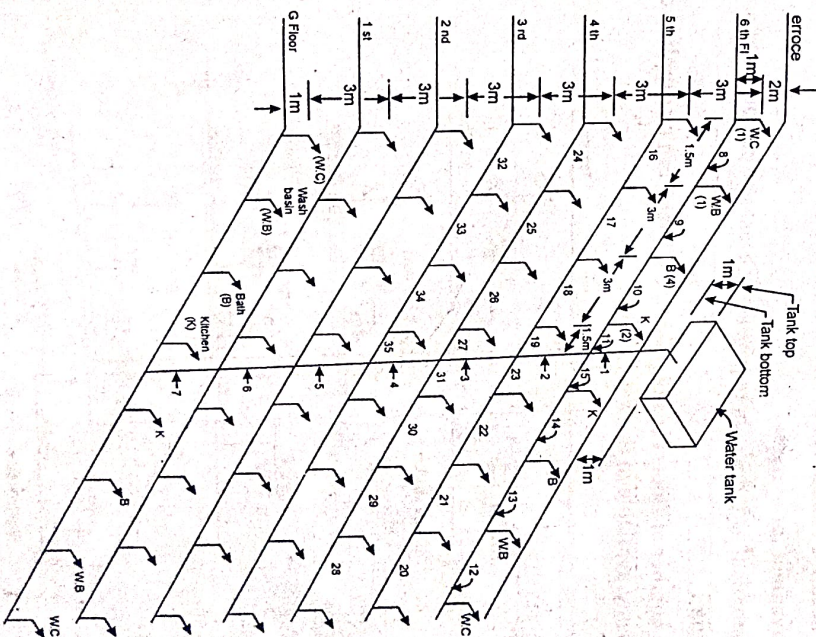


Figure 5.24 Water Piping System (isometric view)

### 5.12 PLUMBING OR PIPING SYSTEMS IN BUILDINGS

The distribution of water within a building can be achieved by the following methods:

1. Piping system using Direct supply.
2. Piping system using Overhead tank
3. Piping system using Underground –Overhead tank
4. Pumped systems
5. Other systems

#### 1. Piping system using direct supply

- Water is supplied to all the fixtures on all floors of the building, directly from the city mains through house connection.
  - This system is successful only when adequate pressure is available in the mains round the clock.
  - Suitable for countries with high water supply standards (like USA) as it eliminates the need for storage tanks, which may cause contamination.
  - Convenient for users.
  - Economical as it does not require storage tanks or pumping units.
- Limitation :**
- The number of floors (or storeys) to which water can be supplied depends on the pressure available in the water mains.

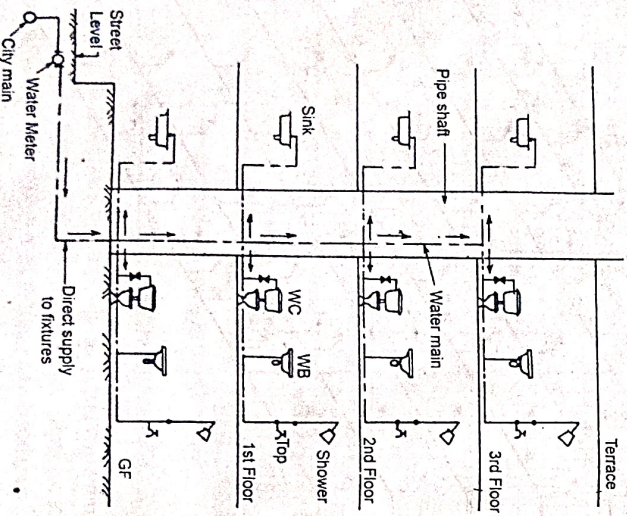


Figure 5.25 Direct Supply

#### Water Distribution and Supply to Buildings

#### 2. Piping system using Overhead tanks

- The water pressure in the municipal mains is not sufficient to reach the top floors of the building throughout the day. The pressure is high only for a limited period in the mornings and evenings.
  - To meet the water demand during non-supply hours, water is stored in overhead tanks, which are filled directly from the municipal mains.
  - The supply to the kitchen is directly from the municipal mains.
  - The supply for bathing and flushing is from the overhead tanks.
  - This system is common in Indian houses, hotels and restaurants.
- Limitation :**
- Drinking water has to be stored in vessels during the daily supply hours.

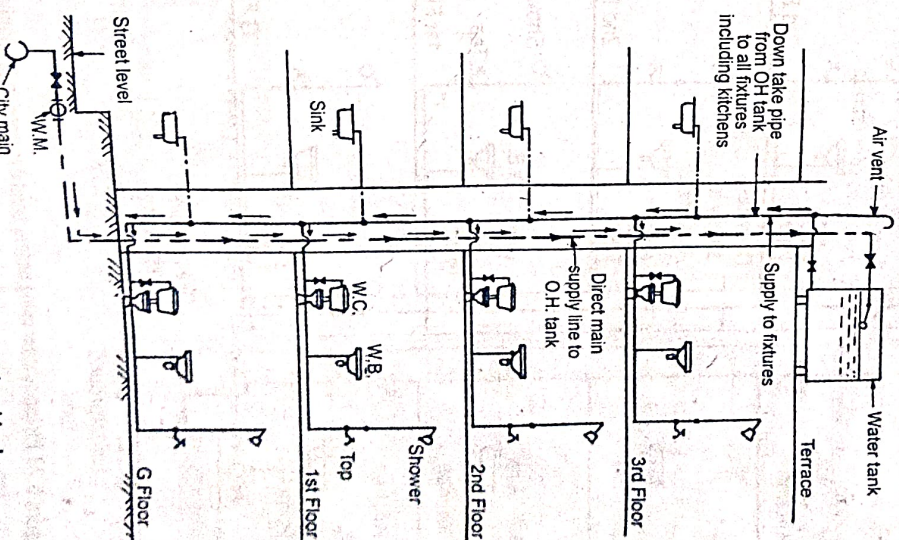


Figure 5.26 Piping system using Overhead tank

3. Piping system using Underground – Overhead tank supply

- When the municipal supplies are at low pressure; whether continuous or intermittent, it becomes necessary to store water in underground storage tanks.
- In this system, direct pumping from mains is prohibited.
- Water from the underground tank is pumped to the overhead tank.
- Water is then supplied to all the fixtures from the overhead tank.
- Domestic R.O. filters may be essential to obtain safe drinking water.

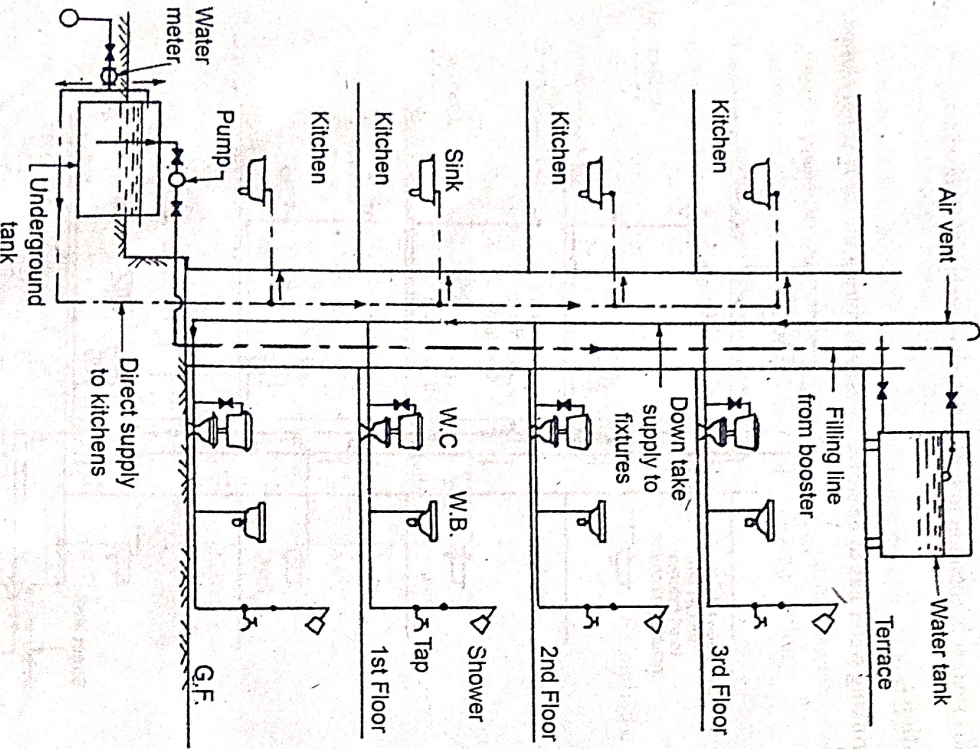


Figure 5.27 Piping system using underground Overhead tank supply.

Water Distribution and Supply to Buildings

4. Pumped Systems – Hydro-Pneumatic System

- It is a high pressure distribution system.
- This system is ideal for existing buildings where overhead tanks cannot be constructed and also when overhead tanks cannot generate sufficient pressure at top floors.
- Water is distributed by an automatic pumping system directly to the supply point.
- There is no need of overhead tanks.
- The pressure is boosted by pumping sets that pump water from underground or ground level tanks.

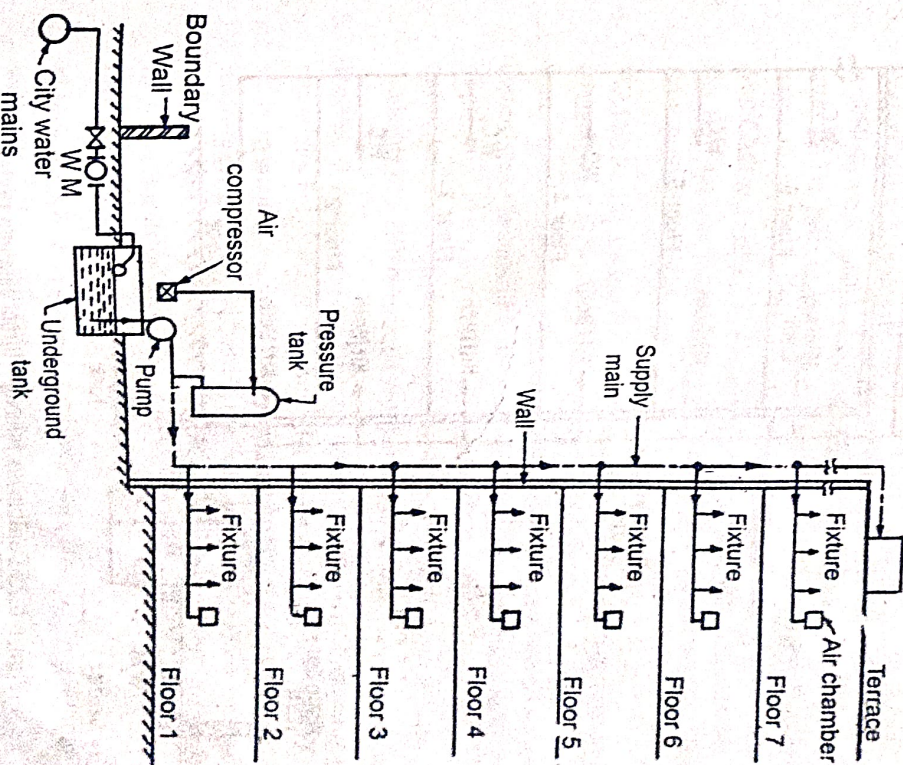


Figure 5.28 Pumped Systems (or) Hydro-Pneumatic Piping System

### 5. Other Systems – Continuous running systems

- Water is directly supplied to the point of use.
- This system is used where the demand is constant and matches with the pump capacity.

**Example :**

Air conditioning cooling towers, Steam boilers and Industries.

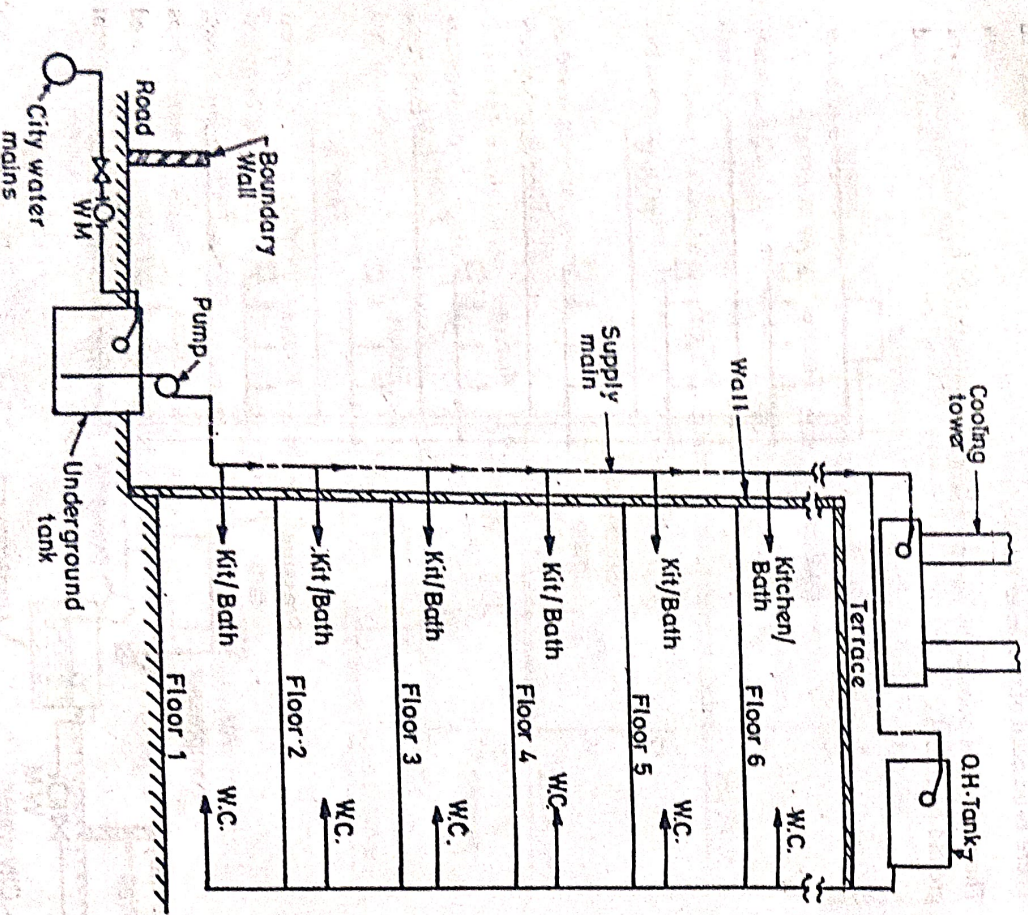


Figure 5.29 Continuous running – Direct pumping system

### 5.13 COMPUTER APPLICATIONS IN DISTRIBUTION NETWORKS

The following software are used in the design of Water Distribution Networks (WDNs):

1. **EPANET:** Public domain software which can be efficiently used to design any sort of network. It provides a variety of advantages like water quality analysis, extended period simulation, residual chlorine calculations for disinfection etc. It can also be used to renovate or restore the existing water supply systems.
2. **BRANCH:** Public domain optimization software in which program is developed to design the branched water distribution networks. Branch software takes certain parameters like elevation data, pipe lengths, coefficient of friction and demand of nodes as inputs over the cost as function. The output is optimized length and diameters of pipes so that overall cost of network is the least one.
3. **WaterCAD & WaterGEMS :** These are easy to use and versatile water distribution as well as water quality modeling software package accepted for a variety of applications: hydraulic modeling, water quality modeling and analysis, steady state and extended period simulations, strong data management, integration with AutoCAD and GIS, simple model building with geospatial modules and tools, fire flow analysis, optimization and control of distribution network variables like flow, pressure, velocity etc.
4. **WATSYS:** It is a water distribution simulation and modeling software based on Geographical Information System (GIS). It is efficiently used for designing new water distribution as well as for up-gradation of existing distribution networks. It comprises of features like colour-coded plans for making colourful visualizations of pressure, elevations and flows at different nodes, easy importing and exporting data files, in-built pipe catalogue etc. It is efficiently used for simulation and modeling of different types of distribution networks.
5. **DisNet:** It is powerful and efficient water distribution software and offers great simplicity in building water distribution networks. Maximum accuracy in output with optimum input details. It is used in the design of water distribution, stream hydrology, generation of unit hydrographs and establishing interrelationships between them. It is integrated with CAD as its inbuilt management tool and used in modeling different types of water distributions networks for different topographical conditions.
6. **HydraulicCAD:** It is an AutoCAD based water distribution software integrated with EPANET hydraulic analysis program. It possesses a feature of building query for addition and editing of different hydraulic parameters like head loss, pressure,

flow of distribution networks. It provides inbuilt pipe catalogue which consists of detailed information about pipe material, classes and sizes. It is also used for fire flow analysis.

7. **KYPIPE or Pipe:** Hydraulic modeling software package which has strong computational algorithm for the fluids essentially water. It can be used for the designing and selection of pumps, valves, tanks as well as pipes.

Other software available are: **LOOP, AQUIS, H2O map, H2O net, Synergi Water, HYDROFLO3 etc.**