MODULE- 1

Introduction

➢ Human Activities and environmental Pollution

1.Agriculture

- The environmental impact of irrigation includes the changes in quantity and quality of soil and water.
- Adverse effects of agriculture are soil erosion, contamination of water due to use of chemical fertilizers and pesticides, water logging etc.
- Discharge of nutrients into water bodies
- Discharge of pesticides into the environment
- Imposing burden on water resources.
- Deforestation
- Submergence of forest and other lands
- Evacuation and rehabilitation of people and villages
- Disturbance of wild life
- Mosquito breeding.
- Settled agriculture has increased food supply that lead to support more people, but decrease the environment quality.

2.Housing

- Use of large volume of materials for building industry and transportation of materials to construction sites causing high rate of consumption of natural resources.
- Extraction of constructional materials. Ex Sand, Boulders, Pebbles, Iron ore….ext.
- Cutting of forests
- Energy utilization
- Stress on water resources
- Urban centers impose heavy burden on the environment
- Disruption of storm water drainage patterns.

3. Energy Industry

- The environmental impact of energy harvesting and consumption is diverse.
- Thermal power plant consumes Coal, Natural gas etc… which may lead to global warming.
- In the real world of consumption of fossil fuel resources which lead to global warming and climate change.

- Stress On Water Resources
- Urban Centers Impose Heavy Burden On The Environment
- Disruption of Storm Water Drainage Patterns.
- Deforestation For Constructing Roads And Railways
- Air Pollution
- Noise Pollution
- Disruption Of Wildlife Habitats
- Pollution Of Marine Water Due To Harbors
- Pressure On Land And Other Natural Resources For Raw Material.
- Pressure On Transport System.

4.Mining- The environmental impact of mining includes

- Deforestation
- Large tracts of land are made barren.
- Soil erosion
- The transportation of ores impose heavy burden on transport facilities.
- Noise pollution
- The environmental impact of mining includes formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes.
- In some cases, additional forest logging is done in the vicinity of mines to increase the available room for the storage of the created debris and soil. Besides creating environmental damage, contamination resulting from leakage of chemicals also affect the health of the local population.
- Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned to close to its original state. Some mining methods may have significant environmental and public health effects.

5. Transportation activities-

- The environmental impact of transport is significant because it is a major user of energy, and burns most of the world's petroleum.
- This creates air pollution, including release of nitrous oxides and particulates, and is a significant contributor to global warming through emission of carbon dioxide, for which transport is the fastest-growing emission sector. By subsector, road transport is the largest contributor to global warming.
- Adverse effects on environment- air pollution, consumption of natural resources like petrol, diesel at faster rate

6. War

- As well as the cost to human life and society, there is a significant environmental impact of war. Scorched earth methods during, or after war it has been in use for much of recorded history but with modern technology war can cause a far greater devastation on the environment.
- Usage of Nuclear weapons, which lead to increases radioactive components into the environment.

7. Manufactured products

- The environmental impact of cleaning agents is diverse. In recent years, measures have been taken to reduce these effects.

Paint- The environmental impact of paint is diverse. Traditional painting materials and processes can have harmful effects on the environment, including those from the use of lead and other additives. These include usage of solvents, dispersing agents, dies etc. Which intern results in the release of volatile organic compounds such as methylene chloride, ethylene chloride, benzene etc…

Paper- The environmental impact of paper is significant, which has led to changes in industry and behavior at both business and personal levels. With the use of modern technology such as the printing press and the highly mechanized harvesting of wood, paper has become a cheap commodity.

Pesticides- The environmental impact of pesticides is often greater than what is intended by those who use them. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non target species, air, water, bottom sediments, and food. Pesticide contaminates land and water when it escapes from production sites and storage tanks, when it runs off from fields, when it is discarded, when it is sprayed aerially, and when it is sprayed into water to kill algae.

8. Water resource projects – which includes construction of Dams, Irrigation canals, channels, weirs, etc

- Imposing burden on water resources.
- Deforestation
- Submergence of forest and other lands
- Water logging problems
- Evacuation and rehabilitation of people and villages
- Disturbance of wild life

Need for protected water supply.

- Protected water supply means the supply of water that is treated to remove the impurities and made safe to public health. Water may be polluted by physical and bacterial agents.
- The protected water supply system is only available in urban areas and only to some extent in rural areas. But the country like India is essentially a village based country and majority of population which lives in rural villages need safe and portable water for usage.
- Most of the rural population if not provided with protected water supply systems. They are mostly depending upon the conventional sources like wells, ponds and streams etc are generally in polluted condition.
- People consuming this water without any treatment they are bound to suffer from water borne diseases like typhoid, dysentery, cholera, poliomyelitis, Jaundice, gunia worm etc.

- The rural water supply system aim to provide reasonable quantity of safe wholesome water to satisfy demands of people and thus helping in maintaining better sanitation and beautification of surroundings, thereby reducing environmental pollution.

The Per Capita Demand (q)

It is the annual average amount of daily water required by one person, and includes the domestic use, industrial and commercial use, public use, waster etc. It may, therefore, be expressed as

Per Capita Demand (q) in litres per day per head

$$= \frac{\text{total yearly water requirements of the city in liters (i.e. V)}}{\text{365 X Design population}}$$

Total yearly water requirement of the city can, therefore, be worked out by using above equation, provided the per capita demand is known or assumed.

For an average Indian town, the requirement of water in various uses is as under

i.	Domestic purpose	135 litres/c/d
ii.	Industrial use	40 litres/c/d
iii	Public use	25 litres/c/d
iv.	Fire Demand	15 litres/c/d
v.	Losses, Wastage and thefts	55 litres/c/d

Total : 270 litres/capita/day

Factors affecting Per Capita Demand

(1) Size of the city. The per capita demand for big cities is generally large as compared to that for smaller towns. This is because of the fact that in big cities, huge quantities of water are required for maintain clean and healthy environments. For example, big cities are generally sewered, and as such require large quantities of water (a sewered house requires four to five times the water required by an unsewered home). Similarly, in a big city, commercial and industrial activities are generally more, thus requiring more water. Affluent rich living in air cooled homes may also increase the water consumption in cities.

(2) Climatic Conditions. As hotter and dry places, the consumption of water is generally more, because more of bathing, cleaning, air cooling, sprinkling in lawns, gardens, roofs, etc., are involved. Similarly, in extremely cold countries more water may be consumed, because the people may keep their taps open to avoid freezing of pipes, and there may be more leakage from pipe joints, since metals contract with cold.

(3)Types of luxury used and Habits of people. Rich and upper class communities generally consume more water due to their affluent living standards. Middle class communities consume average amounts.

(4) Industrial and Commercial Activities. The pressure of industrial and commercial activities at a particular place increases the water consumption by large amounts. Many industries require really huge amounts of water (much more than the domestic demand), and as such, increase the water demand considerably.

(5) Quality of Water Supplies. If the quality and taste of the supplied water is good, it will be consumed more, because in that case, people will not use other sources such as private wells, hand pumps, etc. Similarly, certain industries such as boiler feeds, etc., which require standard quality waters will not develop their own supplies and will use public supplies, provided the supplied water is up to their required standards.

(6) Pressure in the Distribution System. If the pressure in the distribution pipes is high and sufficient to make the water reach at 3rd or even 4th storey, water consumption shall definitely be more.

(7) Development of Sewerage Facilities. As pointed out earlier, the water consumption will be more, if the city is provided with 'flush system' and shall be less if the old 'conservation system' of latrines is adopted.

(8) System of Supply. The water may be supplied either continuously for all the 24 hours of the day, or may be supplied only of peak periods during the morning and evening. The second system, i.e, the intermittent supplies, may lead to some saving in water consumption due to losses occurring for lesser time and a more vigilant use of water by the consumers.

(9) Cost of Water. If the water rates are high, lesser quantity many be consumed by the people. This may not lead to large savings as the affluent and rich people are little affected by such policies.

(10) Policy of Metering and Method of Charging. Water tax is generally charged in tow different ways:

(a) On the basis of meter reading (meters fitted at the head of the individual house connections and recording the volume of water consumed).

(b) On the basis of certain fixed monthly flat rate.

<u>**VARIATIONS IN DEMAND. (q)**</u>

The per capita demand (q), so far discussed, has been based upon the annual consumption of water. It was, therefore, defined as the **annual average daily consumption** per person.

There are wide variations in the use of water in different seasons, in different months of the year, in different days of the month, in different hours of the day, and even in different minutes of the hour.

1) **Seasonal variations.** The water demand varies from season to season. Occur due to larger use of water in summer season, lesser use in winter, and much less in rainy season. These variations may also be caused by season use of water in industries such as processing of cash crops at the time of harvesting, etc.
    - **Maximum seasonal consumption= 1.3 times of annual average daily rate of Demand**

2) **Daily variation.** Day to day variation is called **daily variation.** This variation depends on the general habits of people, climatic conditions and character of city as industrial, commercial or residential. For example, the water consumption is generally more on Sundays and holidays, on days of dust storms, etc.

- **Maximum Daily consumption= 1.8 times the average demand**

3) **Hourly variation.** Again there are variations in hour to hour demand called hourly variations. For example, the consumption in the early hours of morning (0 to 6 hours-say) is generally small, increases sharply as the day advances, reaching a peak value between about 8 to 11 AM, then decreases sharply upto about 1 PM, remains constant upto about 4 PM, again increases in the evening reaching a peak between 7 to 9 PM, finally falling to a low value in the late hours of night, as shown if Fig.

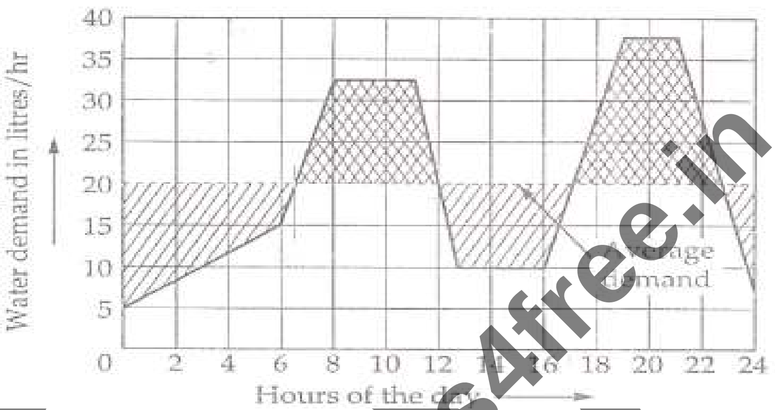


Fig : Showing hourly rate of water consumption.

- **Maximum hourly consumption= 1.5 times the average demand**

The determination of this hourly variations is most necessary, because on its basis the rate of pumping will be adjusted to meet up the demand in all hours.

PEAK FACTOR

- Maximum hourly consumption of the maximum day is called **Peak demand.** Which is nothing but a factor of safety.

The GOI manual on water supply has recommended the following values of the **Peak factor,** depending upon the population:

Table : Peak Factors

S. No.	Population	Peak factor*
Up td. 5	i) upto 50,000 ii)50,001-2,00,000 iii)Above 2 lakhs	3.0 2.5 2.0
2.	For Rural water supply schemes, where supply is effected through stand post for only 6 hours.	3.0
2 .		

- Evidently, the peak factor tends to reduce with increasing population, since the different habits and customs of several groups in larger population, tend to minimize the variation in demand pattern.

DESIGN PERIODS

Water supply projects are designed to serve over a specified period of time after completion of the project. This time period is called **Design period.**

OR

A water supply scheme includes huge and costly structures (such as dams, reservoirs, treatment works, penstock pipes, etc.) which cannot be replaced or increased in their capacities, easily and conveniently. For example, the water mains including the distributing pipes are laid underground, and cannot be replaced or added easily, Without digging the roads or disrupting the traffic In order to avoid these future complications of expansions, the various components of water supply scheme are purposely made larger, so as to satisfy the community needs for the reasonable number of years to come. 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.**

Factors Governing the Design Period

1. Useful life of the pipes, structures and equipment used in the water works and the chances of their becoming old and absolute. The design period should not exceed those respective values . If the useful life is more, design period is also more.
2. The anticipated rate of growth of population. If the rate is more, design period is less.
3. The rate of interest of loans taken for the construction of the project. If this rate is more the design period will be less.
4. The rate of inflation during the period of repayment of loans. When the inflation rate is high, a longer design period is adopted.
5. Efficiency of component units of the project during the early years of working, when they are not loaded to their capacity. The more the efficiency, the longer the design period.

Demand of Water

Before designing a proper water works project, it is essential to determine the quantity of water that is required daily.

Types of water demand:-

(i) Domestic water demand
(ii) Industrial water demand
(iii) Institution and commercial water demand
(iv) Demand for public use
(v) Fire demand

(1)Domestic water demand

This includes the water required in residential buildings for drinking, cooking, bathing, lawn sprinkling, gardening, sanitary purposes etc. The amount of domestic water consumption per person shall vary according to the living conditions of the consumers. As per IS 1172-1993, the minimum domestic consumption for a town or a city with full flushing system should be taken at 200l/h/d .

Table 1: Minimum domestic water consumption for Indian towns and cities with full flushing systems as per IS 1172-1993.

Use	Consumption in liters per head per day(l/h/d)
Drinking	5
Cooking	5
Bathing	55
Washing of clothes	20
Washing of utensil	10
Washing and cleaning of ho	10
Flushing of water closets etc.,	30
TOTAL	135

(2) Industrial water demand.

Industrial require a large volume of water for manufacturing processes, cooling operation, steam generation, for processing and sanitation purposes etc, this part of water in known as 'industrial demand'.

In industrial cities, the per capita water requirement may finally be computed to be as high as 450 liter/person/day or so, as compared to the normal industrial requirement of 50 liters/person/day.

(3) Institutional and commercial water demand.

On an average, a per capita demand of 20 liters/head /day is usually considered to be enough to

POPULATION FORECASTING

The various methods which are generally adopted for estimating future populations by engineers are described below. Some of these methods are used when the design period is small, and some are used when the design period is large. The particular method to be adopted for a particular case or for a particular city depends largely upon the factors discussed in these methods, and the selection is left to the discretion and intelligence of the designer.

1) Arithmetical Increase Method

This is the most simple method of population forecast, though it generally gives lower results. In his method, the increase in population from decade to decade is assumed constant. Mathematically, this hypothesis may be expressed as,

$$dp/dt = K$$

Where dp/dt is the rate of change of population and K is a constant. From the census data of past 3 or 4 decades, the increase in population for each decade is found, and from that an average increment is found. For each successive future decade, this average increment is added. The future population P_n after n decades is thus given by,

$$P_n = P_0 + nx$$

Where P_n = future population after n decades

P_0 = present population

x = average increment for a decade.

- ❖ This method should be used for forecasting population of those large cities, which have reached their saturation population.

2) Geometrical increase method.

This method is based on the assumption that the ***percentage increase*** in population from decade to decade remains constant. In this method the average percentage of growth of last few decades is determined, the population forecasting is done on the basis that percentage increase per decade will be the same. This method is also therefore known as ***uniform increase method.***

The population at the end of 'n' decades is calculated by

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

Where P_0 = Initial population; i.e the population at the end of last known census.

P_n = Future population after **n** decades.

r = Growth rate (%)

This growth rate (r) can be computed in several ways from the past known population data. one method is to compute r, as

$$r = \sqrt{}(P_2/P_1 - 1$$

Where P_1 = Initial known population

P_2 = Final known population

t = Number of decades between P_1 and P_2.

(or)

The average may again be either the **arithmetic average**. i.e

$$r = \frac{r_1+r_2+r_3+r_4\ldots+r_t}{t}$$

OR

geometrical average i.e. $r = \sqrt{r_1 r_2 r_3 r_4 \ldots r_t}$

3) Method of Varying Increment *or* Incremental Increase Method.

The method combines both the arithmetic average method and the geometrical average method. From the census data for the past several decades, the actual increase in each decade is first found. Then the increment in increase in each decade is first found. From these, an average increment of the increases (known as incremental increase) is found. The population in the next decade is found by adding to the present population the average increase plus the average incremental increase per decade. The process repeated for the second future decade, and so on. Thus the future population at the end of n decades is given by:

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

Where P_0 = present population

x = average increase per decade

y = average incremental increase

n = number of decades.

4) Decreasing Rate of Growth Method. Since the rate of increase in population goes on reducing, as the cities reach towards saturation, a method which makes use of the decrease in the percentage increase, is many a times used, and gives quite rational results. In this method, the average decrease in the percentage increase for each successive decade. This method is however, applicable only in cases, where the rate of growth shows a downward trend.

5) Simple Graphical method. In the method, a curve is drawn between the population P and time T, with the help of census data of previous few decades, So that the shape of the population curve is obtained – up to the present period. The curve is then carefully is then carefully extended from the present to the future decades. From the extended part of the curve, the population at the end of any future decade is approximately determined.

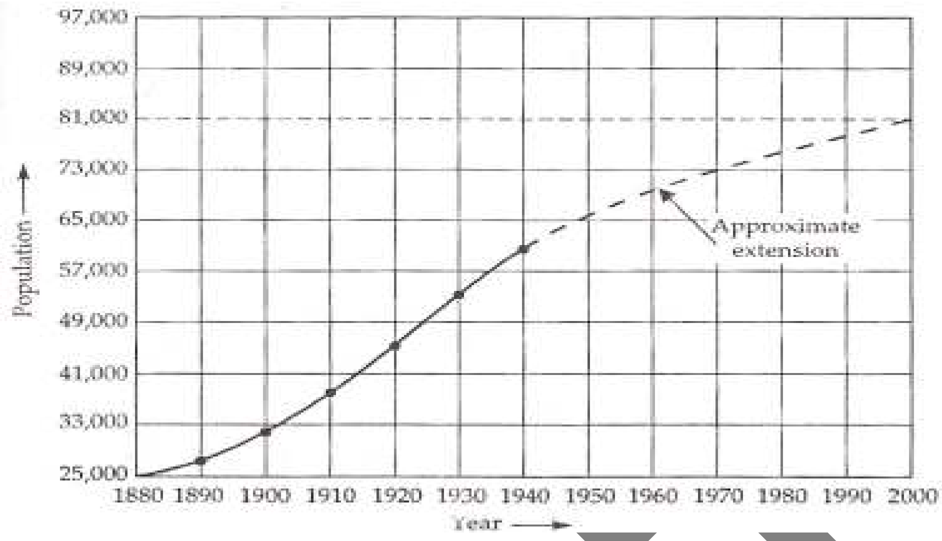


Fig: Graph between population and time

6) **Comparative Graphical Method.**

This method is a variation of the previous method. It assumes that the city under consideration will develop as similar cities developed in the past. The method consists of plotting curves of cities that, one or more decades ago, had reached the present population of the city under consideration.

Thus, as shown in Fig, the population of city A under consideration is plotted upto 1970 at which its population is 62,000. The city B having similar conditions, reached the population of 62,000 in 1930 and its curve is plotted from 1930 onwards. Similar curves are plotted for other cities C, D and E which reached the population of 62000 in 1925, 1935 and 1920 respectively. The curve of city A can be then be continued (shown by dotted line), allowing it to be influenced by the rate of growth of the larger cities. In practice however, is difficult to find identical cities with respect to population growth.

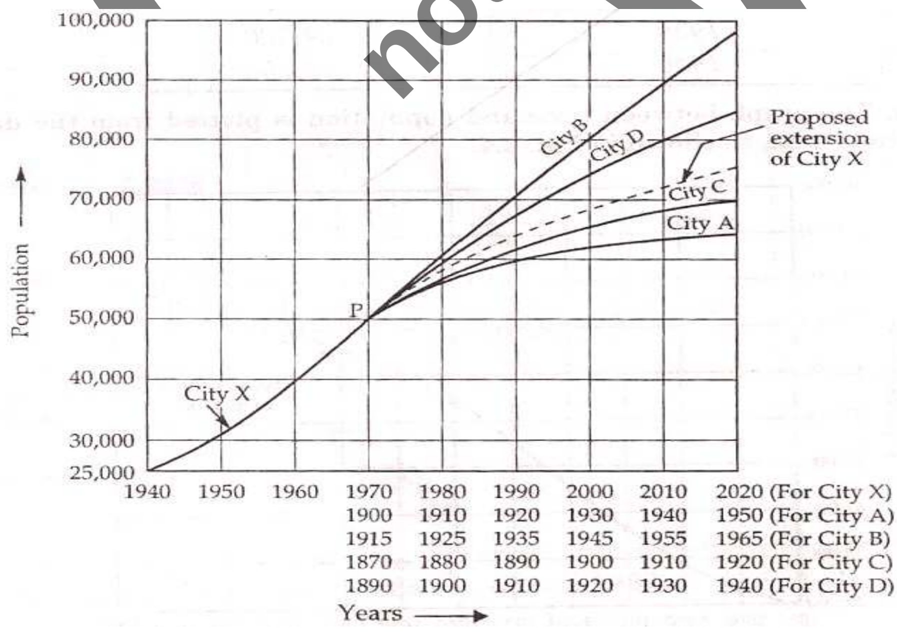


Fig: Comparative Graphical Method

7) **Zoning Method or Master Plan Method.**

This is probably a scientific method using the limitations imposed by the town planner in the increase in density of population of various parts of the city. For this, a master plan of the city is prepared, dividing it into various zones such as industrial, commercial, residential and other zones. Each zone is allowed to develop as per master plan only. The future population of each zone, when fully developed can be easily found. For example, sector A of a residential zone has 1000 plots. Allowing 5 persons per plot, the population of this sector, when fully developed, will be 1000 X 5= 5000 persons. Similarly, the development of each zone can be estimated. This method is more advantageous because of the fact that the total water requirement of the city depends not only of domestic purposes, but also for commercial, industrial, social health and other purposes.

8. <u>Ratio and Correlation method</u>

The population growth of a small town or area is related to big towns or big areas. The increase in population of big cities bears a direct relationship to the whole state or country. In this method, the local to national (or state) population ratio is determined in the previous two to four decades. Depending upon condition or other factors, even changing ration may be adopted. These ratios may be used in predicting their future population. This method takes into account the regional and national factors affecting population growth. This method is useful for only those areas whose population growth in past is fairly consistent with that of state or nation.

9. <u>Growth Composition Analysis Method</u>

The change in population of a city is due to three reasons: (i) birth, (ii) death, and (iii) migration from villages or other towns. The population forecast may be made by proper analysis of these three factors. The difference between birth rate and death rate gives the natural increase in the population . Thus,

$$P_n = P + \text{Natural increase} + \text{Migration.}$$

The estimated increase is given by the following expression:

$$\text{Natural increase} = T(I_B P - I_D P)$$

Where T= design (forecast) period

P= present population.

I_B = average birth rate per year.

I_D = average death rate per year.

10) <u>The logistic curve method.</u> It is explained earlier that under normal conditions, the population of a city shall grow as per the ***logistic curve.*** **Verhulst** has put forward a mathematical solution for this mathematical solution for this logistic curve. According to him, the entire curve can be represented by an autocatalytic first order equation, given by,

$$\log_e\left(\frac{P_s - P}{P}\right) - \log_e\left(\frac{P_s - P_0}{P_0}\right) = -K P_s . t \quad ...(2.20)$$

where P_0 = The population at the start pt. of the curve A.

P_s = Saturation population.

P = Population at any time t from the origin A.

K = Constant.

From Eq. (2.20), we get

$$\log_e\left[\left(\frac{P_s - P}{P}\right) \times \left(\frac{P_0}{P_s - P_0}\right)\right] = -K P_s t$$

or
$$\left(\frac{P_s - P}{P}\right)\left(\frac{P_0}{P_s - P_0}\right) = \log_e^{-1}(-K.P_s.t.)$$

or
$$\frac{P_s - P}{P} = \left[\frac{P_s - P_0}{P_0}\right] \log_e^{-1}(-K.P_s.t)$$

or
$$\frac{P_s}{P} - 1 = \left[\frac{P_s - P_0}{P_0}\right] \log^{-1}(-K.P_s.t.)$$

or
$$\frac{P_s}{P} = 1 + \left[\frac{P_s - P_0}{P_0}\right] \log_e^{-1}(-K.P_s.t.)$$

or
$$P = \frac{P_s}{1 + \frac{P_s - P_0}{P_0} \log_e^{-1}(-KP_s.t.)} \quad ...(2.21)$$

Substituting $\frac{P_s - P_0}{P_0} = m$ (a constant)

and $-K.P_s = n$ (another constant)

we get

$$\boxed{P = \frac{P_s}{1 + m.\log_e^{-1}(nt)}} \quad ...(2.22)$$

This is the required equation of the logistic curve. McLean further suggested that if only three pairs of characteristic values P_0, P_1, P_2 at times $t = t_0 = 0$, t_1, and $t_2 = 2t_1$ extending over the useful range of the census populations, are chosen, the saturation value P_s and the constants m and n can be evaluated from three simultaneous equations, as follows :

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2} \quad ...(2.23)$$

$$m = \frac{P_s - P_0}{P_0} \quad ...(2.24)$$

$$n = \left(\frac{1}{t_1}\right)\log_e\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right] \quad ...(2.25)$$

$$= \frac{2.3}{t_1}\log_{10}\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right] \quad ....(2.25a)$$

Knowing P_0, P_1 and P_2 from census data and using them in these equations, the values of P_s, m and n are known, and the equation of the logistic curve (Eq. 2.22) is thus known. From that, the population P at any time t can then be obtained, as explained in the example given below.

Filtration

Filtration is one of the most important operation followed by sedimentation.

In sedimentation large portion of suspended particles are removed but fine floc material and micro organisms are not effectively removed.

In filtration turbidity and colloidal matter of non settlable types are removed.

Theory of filtration

The following actions take place in theory of filtration.

(i) Mechanical straining
(ii) Sedimentation
(iii) Biological Action
(iv) Electrolytic Action

[Detailed explanation in last sheets]

Rapid sand filteration | Rapid gravity sand filteration.

1. Enclosure tank.
2. Filter media
3. Base material.
4. Underdrainage system.
5. Appurtenances.

1. Enclosure tank :- It is rectangular in shape. Made of concrete or masonary structure. It is usually coated with water proofing material.

(*) Depth of the tank may vary b/w 2.5m - 3.5. Each unit may have a surface area of 20 to 50m². They are arranged in series.

(*) The length and width ratio is normally kept b/w 1.25 to 1.35m

(*) It has a underdrain pipe connected at the bottom of the tank. Along with the underdrain it also has a trough running across the length or width of the wall for distribution of water to be filtered during normal operation and for collection of wash water during cleaning operation.

3) Filter Media

- ⊛ The sand used as filter media should be free from dirt, organic matter and other suspended matter.
- ⊛ When finer suspended particles is to be removed smaller is the sand size. Rapid sand filter will have effective size between 1.2 to 1.7, commonly 1.5.

- ⊛ Due to increase effective size and decreased uniformity of grain size, the void space is increased and results in effective filtration.
- ⊛ The fine sand usually lie at the top of the bed and coarse grain size lie at the bottom. The depth of the sand media varies b/w 0.6–0.9m
- ⊛ Sometimes crushed antracite ~~has been~~ also will be used as filter media instead of sand. But it is costlier in comparison to sand. The crushed antracite has an effective size of 0.70 to 0.75mm and uniformity co-efficient not over 1.75

Base material :- The filter sand media is supported on base material consisting of graded gravel layer.

The gravel should be hard & durable. And The total depth varies from 45 to 60cm.

Under drainage system.

1> It collects the water uniformly over the area of gravel bed.

2> It provides uniform distribution of back-wash water without disturbing or upsetting the gravel bed and filter media.

There are many underdrainage system.

1> Perforated pipe system.

2> Pipe & strainer system.

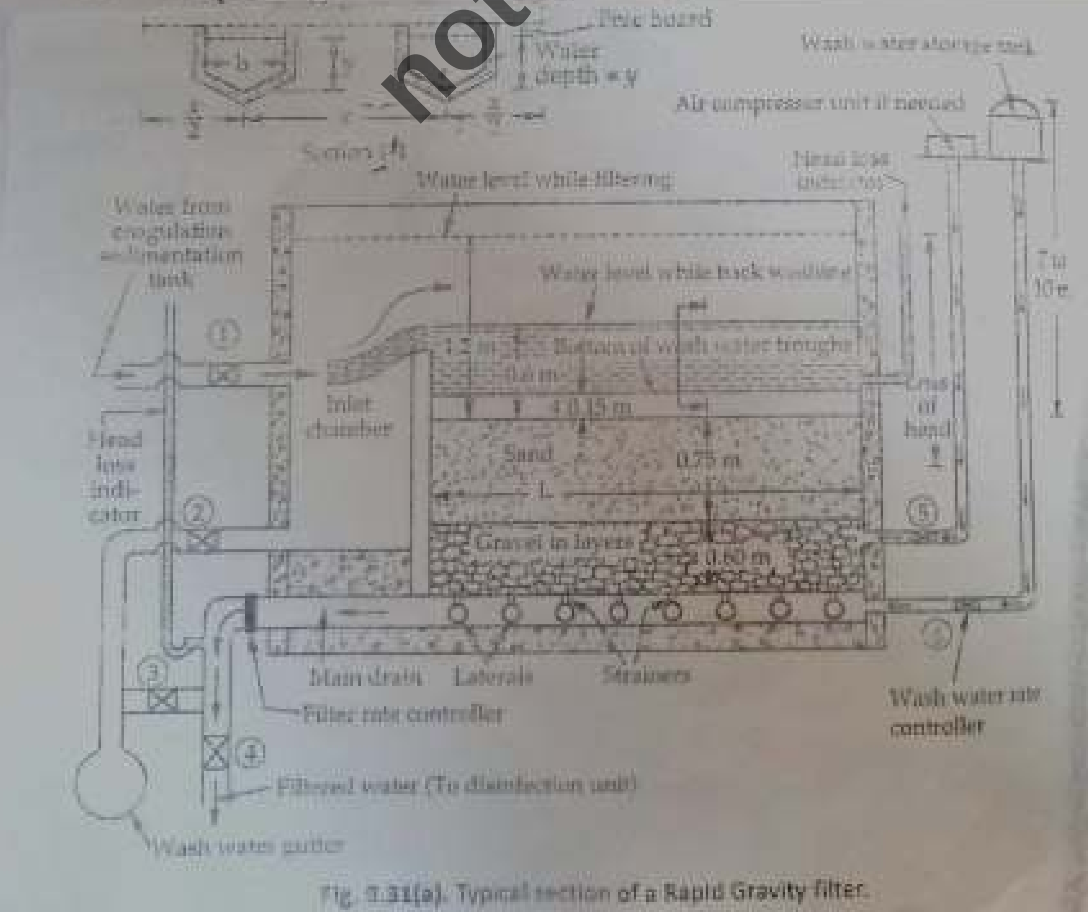


Fig. 3.31(a). Typical section of a Rapid Gravity filter.

Working & cleaning of Rapid Gravity filters

Valve NO	Name of valve
1 →	Inlet valve
2 →	waste water valve to drain water from inlet chamber
3 →	w/w valve to drain water from main drain
4 →	Filtered water supply valve
5 →	compressed air valve
6 →	wash water supply valve.

Valve 1 is opened the effluent to enter into filteration unit and once filtered it has to be taken out of and so valve 4 is kept open.
So when the filter is in working condition valve 1 & 4 are open.

Backwashing

- When sand is dirty its time to wash it. The intake water has to be stopped and so there will be no outlet as well. Thus valve (1) & (4) are closed.

- The wash water is sent backward upward through the filter bed. This forced upward movement of washwater and compressed air will agitate the sand particles thus removing suspended impurities from it. For this process valve 5 & 6 are opened.

- After completing the backwashing process valve 5 & 6 is closed and valve 2 is opened to collect the wash water

Next valve 2 & 6 are closed and valves ① & ③ are opened. This allows fresh water to enter the filter unit for filtration process and all the remaining washwater still getting drained is removed by valve 3. Finally after all wash water is drained, valve 3 is closed & valve 4 is opened.

- The entire process of backwashing the filter takes about 15 minutes.

Slow Sand Filters

Slow sand filter were the earliest type of filter initially used. usually water entering a slow sand filter are given only primary settling without any coagulation as pretreat -ment.

A slow sand filter consist of foll parts.

1> Enclosure tank.
2> Filter media
3> Base material
4> under drainage system.
5> Appurtenances.

CONSTRUCTION OF Slow Sand Filter -

1> Enclosure Tank :- It is usually rectangular in shape built usually below ground level. The tank is either stone or brick masonary with a coating of water proof material

- The floor has a bed slope of 1 in 100 to 1 in 200 towards the central drains
- The surface area of the tank varies between $50m^2$ to $1000m^2$. The filtration rate varies b/w 100 to 200 ltr of water per square metre.
- The depth of the tank varies from 2.5 to 4m.

2> Filter media :- The filter media consist of sand layer, 90 to 110 cm thick. The effective size of sand varies from 0.20–0.35 with a common value of 0.3 usually.

- The co-efficient of uniformity varies from 2 to 3, the common value being 2.5.

- The finer the sand, better will be bacterial removal efficiency but slower will be filter -ation rate.

  When the quality of pretreatment given to water is less, fine sand is more preferable to be used, as it helps in removing better turbidity and bacterial removal.

3> Base material : The filter media is supported on base material consisting of 30 to 75cm thick gravel bed.
  The gravel base is graded and laid in layers of 15cm with topmost layer of finer size and bottommost layer of coarse size.

	Depth		Size
Top most layer	15cm	→	3mm to 6mm
Intermediate layer 1	15 cm	→	6mm to 20mm
Intermediate layer	15cm	→	20mm to 40mm
Bottom layer	15cm	→	40mm to 65mm

4> Under drainage system

The under drainage system placed at the bottom most part of tank collects the filtered water and delivers it to clean water reservoir.

The lateral drains are either earthenware or perforated pipes of 7.5 to 10cm dia.

5> Appurtenances :-

The various appurtenances that are installed for efficient working of filter are devices installed for.

1> Measuring the loss of head to filter media
2> controlling the depth of water above the filter media
3> Maintaining constant rate of flow through the filter.

SAKA... T
Assis... ...sor
De... ... ...

Working of slow sand filter

Water from the plain sedimentation tank enters the slow sand filter unit through inlet. The depth of water over the filter media is usually equal to the thickness of sand medium. Water passes downwards through sand bed, it works by a combination of both straining and microbiological action.

It has 3 zones of purification - Viz. -

1> The surface coating called "SCHMUTZDECKE"
2> The autotrophic zone existing few millimeters below the schmutzdecke &.
3> The heterotropic zone which may extend some 30cm. in the.

- The partly decomed organic matter along with iron, magnesium & silica form reddish brown sticky deposit called 'SCHMUTZDECKE'. This absorbs organic matter in colloidal state.

- After 2-3 weeks of the start of working of S.S filter it forms also an autotropic layer comprising of algae, bacteria, protozoa, suspended particles and organic matter, it helps in the breakdown of decomposable organic matter by utilising nitrogen, phosphate and carbon-di-oxide and it release oxygen thus oxiding the filter.

- In the heterotrophic zone which extends to a depth of 30cm, the bacteria multiply in large number, to break down completely remaining organic matter.

- The difference of water level in the filter basin and the outlet chamber is known as filter head. S.S.F works upto a maximum filter head of 75cm

Problem on slow sand filter

1. A city has a population of 20,000 with an average rate of demand as 150 ltr/capita/day. Find the area of slow sand filters

<u>Solution</u>

(1) Assume max daily demand as 1.5 times average daily demand

(2) Assume average rate of filtration as 150 ltr/hr/m² of the filter area.

Max daily demand = $1.5 \times 20{,}000 \times 150$

= 4,500,000 ltr.

Area of filtration = $\frac{4500000}{150 \times 24} = 1250\,m^2$

Provide 6 filter unit of size

Pressure sand filters.

10.15. PRESSURE FILTERS

The pressure filter is a type of rapid sand filter which is in a closed container and through which the water passes under pressure. The pressure may vary from 3 to 7 kg/cm^2 and may be developed by pumping. It may be either horizontal type or vertical type. The diameter of vertical varies from 2 to 2.5 m and length varies from 2.5 to 8 m. The filter is operated similar to a gravity type rapid filter except that the coagulated water is usually applied directly to the filter without mixing, flocculation or conditioning. Fig. 10.16 (a) shows the diagrammatic sketch of horizontal type pressure filter while Fig. 10.16 (b) shows the vertical type pressure filter.

The uniformity co-efficient and effective size of filter sand is practically the same as that provided for rapid gravity filters, while the thickness of sand bed may vary from 50 to 60 cm. Gravel layers also follow the same practice as in gravity sand filters. The under drainage system may consist of pipe grids or false bottoms. Washing

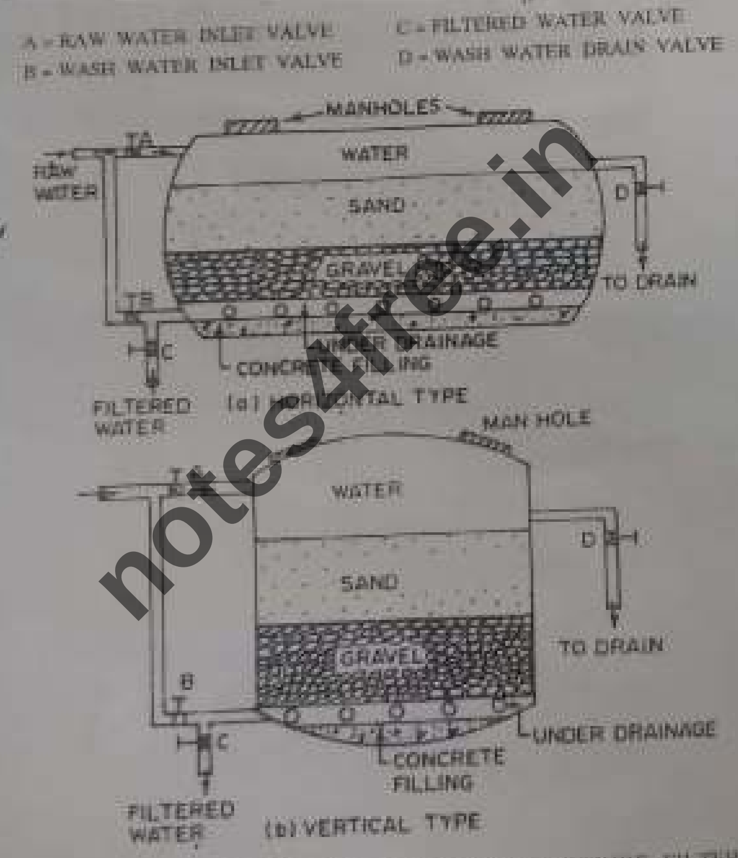


FIG. 10.16. DIAGRAMMATIC SECTIONS OF PRESSURE FILTERS

of filter media is accomplished by reversing the flow by manipulating the valves in the piping. Automatic pressure filters are also available in which backwashing is done automatically after a fixed interval of time or when the head loss has reached a given value.

Pressure filters are particularly advantageous for installations where water is received under pressure, as no pumping after filtration is required. Because the filter container is air tight, this filter may be placed on a pressure line. The only loss of head is that required to force the water through the filter. The filtration rate is much higher than the rapid gravity filter – the rate may vary from 6000 to 15000 litres per hour per m^2 of filter area. Due to this, they are considered as being unreliable in the removal of bacteria. They are, therefore, not used for treating municipal water supplies. They are mostly used in clarifying softened water at industrial plants and in treating swimming pool water that is recirculated.

Operational Problems in Sand Filters

1> Formation of mud balls
2> Cracking of Filters.
3> Air binding.
4> Sand Incrustation.
5> Jetting and sand boils
6> Sand leakage.

Formation of mud balls:

1> The mud from the atmosphere usually accumula-tes on the sand surface, so as to form a dense mat layer. If the filter is not frequently backwashed the mud may sink into deeper layers of sand bed.

2> The mud sticks to the sand grains and other suspended impurities forming mud balls. These mud balls slowly and steadily increase in size and weight and sink down to the layer of gravel and hence interfere with the upward movement of wash water during cleaning

3> The mud balls increase in number there slowly getting filled up in the larger area of filter.

Control measures to prevent the interference caused by formation of mud balls

1> Mud balls may be broken with mechanical rakes, and hence the mud particles are easily washed

2> mud particles can be broken by water stream by using a 10mm ϕ pipe which will hit the water with a force so as to break the mud ball

3> compressed air can be passed along with wash water of sand and also simultaneously using mechanical rake to effectively remove the mud balls.

4 > The sand filter bed is washed first then the same water is withdrawn and allowed to stand a depth 10cm above the sand bed and caustic soda of is added. It is allowed to soak for 12hrs and sand is washed again followed by air wash, though the procedure is lengthy it removes the mud balls.

5] Cracking of Filters

The top layer of sand shrinks and develops cracks. The cracks develop more in sand along the walls of sand filter. This increases pressure on sand during filtration process which in after long run reduces the filtration efficiency. of ~~[illegible]~~

replacement of sand after removing cracked sand is an option to improve the efficiency of filter -ation.

3] **Air binding** - The condition of air binding is caused by the release of dissolved air and gases from water, to form bubbles. These air bubbles occupy the void space of filter media and drainage pore. This trouble will occur if the water is saturated with air

4] **Sand Incrustation** :- Sand incrustation occur due to deposition of sticky gelatinous material from influent water or due to filtration of water which is previously treated with lime. Due to this the sand grains enlarge and the effective size of sand changes.

The problem of lime water can be solved by carbonating the lime water before entering the filter.

SAKALA B.T
Assistant Professor
Department of Civil Engineering

5] **Sand leakage** :- Sand leakage happens when fine grains of sand escape to the bottom as the void spaces get displaced while backwashing.

It can be minimised by properly proportioning the sand and gravel layer.

Theory of filtration

The following actions take place during filtration

1> Mechanical Straining
2> Sedimentation.
3> Biological Action &
4> Electrolytic Action.

1> **Mechanical straining**: When the water passes through the filter media, a simple action takes place. i.e, The suspended particles which are larger than the pore-space of filter media gets trapped, This usually happens in the upper few centimeters of the filter media.

2> **Sedimentation**:- In mechanical straining, only those particles which are larger than void space get removed, in sedimentation finer suspended particles are trapped within the continuously formed voids. The continuous voids of the filter media act as "tube settlers", All the colloids are thus removed in this action

3> **Biological Action**

When the filter is put to use and the raw water is passed through it, during the first few days, the upper layer of sand grain

become coated with reddish brown sticky deposit of partly decomposed organic matter together with Iron, manganese, Aluminium & silica.
After some time, there exist on the upper most layer of sand a film of algae, bacteria & protozoa etc. This film is known as 'Schmutzdecke' or 'dirty skin' which acts as a straining mat. The organic impurities in water become food to different microorganisms.

4> Electrolytic Action :- Filter also removes the particulate matter by electrostatic exchange. The charge of the filter medium neutralises the charge of the floc, thereby permitting the floc to be removed.

Classification of Filters

1> Slow sand Filters
2> Rapid sand filters
   (a) Gravity type filter
   (b) Pressure sand filter.

Water Softening

The reduction or removal of hardness from water is known as water softening. It is not essentially important to soften the water in order to make water safe for public use.

- The main advantage of softening water is to reduce the usage of soap as hardwater doesnt easily form lather with water and hence usage of soap increases.
- In case of Industrial supplies softening of water is important as it leads to formation of scale on boilers and also interfere in the piping system of textile industries

SAKALA B.T
Assistant Professor
Department of Civil Engineering

Types of hardness

1) Temprory hardness or carbonate hardness.
2) Permanent hardness or Non-carbonate hardness.

Carbonate hardness is caused by carbonates & bicarbonates of calcium and Magnesium. It can be removed by boiling or by adding lime.

Permanent or noncarbonate hardness is caused by sulphates, Chlorides and nitrates of calcium and magnesium. It is removed by

Special methods of water softening.

Methods of removing temprory hardness

1> **Boiling** :- Calcium carbonate, being slightly soluble It will be present in water as Calcium bicarbonate.

- It easily dissolves in water c contains CO_2. When such water containing CO_2 is boiled, It expels out CO_2 leading to precipitation of $CaCO_3$. It can be easily removed

$$Ca(HCO_3)_2 + Heat \longrightarrow CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$

Calcium bi-carbonate → Cal-Carbonate [insoluble]

- Magnesium bicarbonate and Magnesium carbonate cannot be removed by boiling as $MgCO_3$ is easily soluble in water.

  Hence Boiling cannot effectively remove temprory hardness caused by magnesium.

- For Large scale water supplies will not opt for boiling method as it is not a feasible method.

- Magnesium Carbonate and Magnesium bicarbona-te are removed by precipitating them as insoluble $Mg(OH)_2$ by treating hard water with lime.

(2) Addition of Lime

When hydrated lime $[Ca(OH)_2]$ is added to water, the foll reactions take place.

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + CaCO_3 \uparrow$$

Mag carbonate, hydrated lime → Mg hydroxide [Insoluble], Cal. carbonate

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2 \downarrow$$

Mg bicarbonate, hydrated lime → Mg hydroxide

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + 2H_2O.$$

Cal bicarbonate

Calcium carbonate and Magnesium hydroxide are precipitated and can be removed.

SAKALA B.T
Assistant Professor
Department of Civil Engineering

Methods of Removing Permanent Hardness

Commonly adopted method for removal of permanent hardness are.

(a) Lime soda process

(b) Base Exchange Process generally called Zeolite Process.

(c) Demineralisation Process.

1. Lime Soda Process

- In this process, lime $Ca(OH)_2$ and soda ash (Na_2CO_3) are added to hardwater. It reacts with calcium & magnesium salts, to form insoluble precipitate of calcium carbonate and magnesium hydroxide $[Mg(OH)_2]$

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2 + Mg(OH)_2\downarrow$$

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow$$

$$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaCl_2$$

$$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaSO_4$$

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$$

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaCl$$

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$$

- From the above eq'n, It is clear that lime helps in removing carbonate hardness caused by calcium and magnesium.
- It reacts with non carbonate hardness of magnesium to convert it into non-carbonate hardness of calcium & is removed by soda.
- Lime also helps in removing free dissolved carbondioxide.

- The sodium salts formed in the abv reaction are soluble in water and its presence is unobjectionable.

- The calcium carbonate and Magnesium hydroxide formed gets precipitated and can be removed by the process of sedimentation.

- Some of it may remain and can create problems in filter media and in pipes of distribution system. To prevent this water is recarbonated by passing CO_2 gas through it

SAKALA B.T
Assistant Professor
Department of Civil Engineering

- In recarbonation process, the insoluble carbonates combine with carbon-di-oxide to form soluble bi-carbonates

- The carbon-di-oxide gas to be blown in water can be produced by burning coke, gas or oil. In recarbonation process even though water regains some of its hardness yet recarbonation is advisable.

- The amount of lime and soda required for softening depends upon the chemical quality of the water & the extent of hardness removal desired.

- Many a times hardwater may primarily contain carbonate hardness and very low amt of non-carbonate hardness, hence for treating such water lime treatment is most suited.

Zeolite or Base Exchange or Cation Exchange Process

(*) Zeolite are natural salt or clay which are hydrated silicates of sodium and alluminium having general formula

$$Na_2O\,Al_2O_3 \cdot SiO_2 \cdot H_2O$$

(*) Naturally occuring zeolite like substances can also be manufactured synthetically and are called as Resigns

(*) The zeolite Resigns have an excellent property of exchanging their cation, and hence during softening process of water, the sodium ions of zeolite get replaced by calcium & Magnesium ions present in hard water.

$$Na_2Z + \begin{matrix} Ca \\ Mg \end{matrix} \begin{cases} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{cases} \longrightarrow Na_2 \begin{cases} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{cases} + \begin{matrix} Ca \\ Mg \end{matrix} \Big\{ Z$$

(*) The calcium and Magnesium zeolite can be regenerated into active sodium zeolite by treating it with 5-10 per cent sol'n of sodium chloride

* A Zeolite softener resembles a sand filter in C filtering medium is Zeolite rather than sand

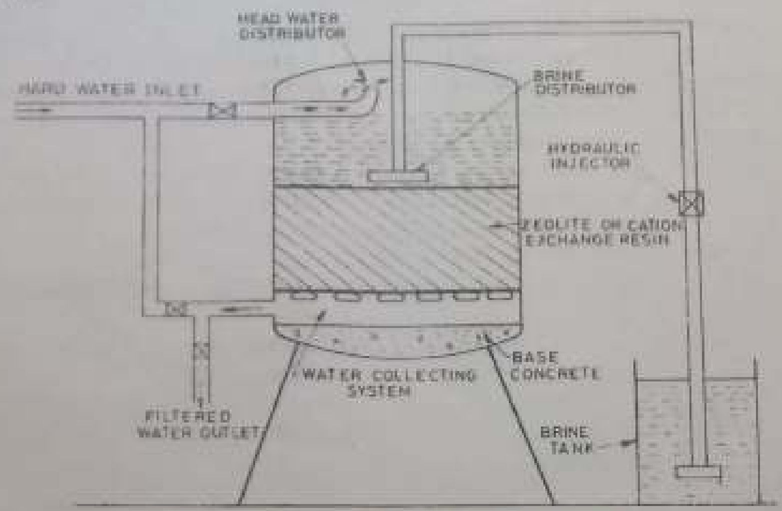
The hard water enters from top and is evenly distri-buted on the entire bed. The softened water is collected through strainers at the base.

* When significant portion of sodium in Zeolite has replaced calcium and Magnesium ions, it is regenerated by reverse flow of water and then by treating with 10% brine solution.

* The excess brine solution is also stripped off by passing clean treated water. The regenerated Zeolite is now ready to be used again.

* Zeolite softeners may be either gravity filters or pressure filters. Usually pressure filters are common among zeolite filters. The rate of filtration is about 300 ltr/m².

* The water treated in a zeolite softener will be free from hardness, it will be 0% hardness which is not suitable for public supplies. Hence a very small portion of unsoftened water is mixed with softened water.



(a) Sectional view

ZEOLITE PROCESS

Advantage of zeolite process

1) water of zero hardness is obtained and hence useful for specific use in textile Industries and boilers etc.

2) The plant is compact, automatic and easy to operate.

3) There is no sludge formation, hence sludge disposal problem is eliminated.

4) The Running, Maintainance and operation [RMO] cost is less hence it is economical.

5) It removes ferrous iron and Manganese from water.

6) water of varying quality of hardness can be treated easily and effective results are obtained.

There is no problem of incrustation of pipes in distribution system as in case of lime soda process.

Disadvantages of Zeolite process

1) Process is not suitable for highly turbid water, as the suspended impurities get deposited around the zeolite particle and thus reduce working efficiency reduces.

2) The process leave sodium bicarbonate as residue which causes problem of foaming in industrial use and in Boilers feed water.

3) It is unsuitable and coastly for treating water containing Iron and Manganese, though it zeolite removes it, it forms Iron Zeolite and Manganese zeolite which cannot be regenerated during chemical rxn into sodium zeolite. Thus zeolite gets wasted.

Demineralisation process for Removing Hardness

The process

* It removes the minerals from water, It helps in completely removing minerals or reducing the mineral content to any desired levels.

* The Demineralised water also is called as de-ionised water, It is as pure as distilled water and is very suitable for Industrial purposes, especially for stream raising in high pressure boilers.

* The process is carried out by passing water through cation exchange resigns products, and then through a bed of anion exchange resigns.

* The process of passing water through cation exchange resign produces almost same effect as zeolite process, except that instead of sodium ions like in zeolite process here we have hydrogen ions as exchange metallic ions.

* The cation exchange resigns are phenol aldehyde condensation products c on sulphonation produces resinous mass having base exchange properties

* Their chemical formula is represented by H_2R where H represents hydrogen Ion and R represents organic part of substance.

The chemical reactions are :

$$Ca(HCO_3)_2 + H_2R \longrightarrow CaR + H_2O + 2CO_2\uparrow$$

Fresh cation exchange resign — Exhausted resign

$$CaCl_2 + H_2R \longrightarrow CaR + 2HCl.$$

$$MgSO_4 + H_2R \rightarrow MgR + H_2SO_4$$

$$2NaCl + H_2R \rightarrow Na_2R + 2HCl.$$

* water coming from cation exchanger will contain diluted carbonic acid, hydrochloric acid, sulphuric acid etc. It is removed by passing the water through a bed of anion exchange resign

* 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 resins used

* The completely demineralised water is sometimes mixed with raw water supplies to obtain the desired mineral content in water

* when the resign is used for longer period of time it needs regeneration & is done as follows

The exhausted cation exchange resigns can be regenerated by treating them with delute hydrochloric acid or sulphuric acid.

(*) The exhausted anion exchange resigns are regenerated by treating them with sodium carbonate solution.

MODULE-5

Quality and Quantity of Surface Water and Their Usefulness for Public water Supplies

Quantity.

- The quantities of available surface waters are dependent upon rainfall. Since on an average, in India, rainfall is sufficient and considerable, there should, therefore, be no scarcity of water in these surface sources.
- But since the rainfall is not uniformly and regularly spread throughout the year, considerable variations in the available flows do occur during the year or years, Thus, the available flow in a stream channel or a river may be too high to be controlled or may be too less to fulfill the demand.
- Storage reservoirs, therefore, provide good means of storing and utilizing rain waters.

Quality.

- The rain water, though pure in the beginning, gets considerably polluted till it reaches the river streams. The gases, dusts, etc., from the atmosphere, get added to the rain water till it reaches the ground; from where onward, it flows on earth's surface and also through drains, channels, etc., which add a lot of organic as well as inorganic impurities to it. Many a times, sewage and industrial wastes get added to this water, making it s contaminated.
- Inorganic impurities like silt, clay, etc., get added due to erosion from the beds of the stream channels. The organic impurities get added in the form of vegetable washings, dead organic matters, and dead animals, etc.
- The inorganic suspended matter, though largely present in direct river or stream waters, get settled considerably in still waters of lakes, ponds and reservoirs. However, the algae weed and plant growth in still waters increase enormously, thus giving colors and tastes to these waters. Surface waters are, however, generally soft and less corrosive than ground waters.
- On the whole, it can be stated that the surface supplies are generally contaminated and cannot be used with minor treatment or without any treatment.
- They, therefore, need building up of proper water treatment plants (WTP s)and other connected works before being used for public supplies. They are useful for big cities and large industrial towns where huge quantities of water are required by the public.

Quality and quantity of sub-surface or underground sources

- The water which gets stored in the ground water reservoir through infiltration is known as the underground water. This water is generally pure, because it undergoes natural filtration during the percolation through the soil pores. Moreover, these waters are less likely to be contaminated by bacteria. However, they generally rich in dissolved salts, minerals, gases, etc. the extent of the salts and minerals present in the ground water depends upon the type and extent of geological formations through which the water is passing before joining the water table.

- Sometimes, the ground water is brought to the surface by some natural processes like springs, and sometimes theses waters are tapped by artificial means by constructing wells, tube wells, infiltration galleries, etc.,
- The replenishment (i.e., filling up) and drainage (i.e., tapping out) of the ground water reservoir is a full topic in itself, involving the hydrological concepts of ground water flow, the possible yields, the construction details of wells, tube wells, galleries, etc.
- Since the ground water is largely tapped in our country for water supplies and there is a scope for its development in future also.

OR

SURFACE SOURCES OF WATER SUPPLIES

Surface sources are those sources of water in which the water flows over the surface of the earth, and is thus directly available for water supplies. The important of these sources are these sources are:

(i) Natural ponds and lakes;
(ii) Streams and rivers; and
(iii) Impounding reservoirs.

These sources are discussed below:

a) Ponds and Lakes as Surface Sources of supplies

- A natural large sized depression formed within the surface of the earth, when gets filled up with water, is known as a pond or a lake. The difference between a pond and a lake is only that of size.
- The quality of water in a lake is generally good and does not need much purification. Larger and older lakes, however, provide comparatively purer water than smaller and newer lakes.
- Self-purification of water due to sedimentation of suspended matter, bleaching of color, removal of bacteria, etc. makes the lake's water purer and better. On the other hand, in still waters of lakes and ponds, the algae, weed and vegetable growth take place freely, imparting bad smells, tastes and colors to their waters.
- The quantity of water available from lakes is, however, generally small. It depends upon the catchment area of the Lake Basin, annual rainfall, and geological formations. Due to the smaller quantity of water available from them, lakes are usually not considered as principal sources of water supplies. They are, therefore, useful for only small towns and hilly areas.
- However, when no other sources are available, larger lakes may become the principal sources of supplies. For example, in Bombay city, water is supplied and brought from lakes about 70 km from there.

b) Streams and Rivers as Surface Sources of Supplies

- Small stream channels feed their waters to the lakes or rivers. Small streams are, therefore, generally not suitable for water supply schemes, because the quantity of water available in them is generally very small, and they may even sometimes go dry.
- They are, therefore, useful as sources of water only for small villages, especially in hilly regions.

- Rivers are the most important sources of water for public water supply schemes. It is a well known fact that most of the cities are settled near the rivers, and it is generally easy to find a river for supplying water to the city.
- The quality of water obtained from rivers is generally not reliable, as it contains large amounts of silt, sand and a lot of suspended matter.
- The disposal of the untreated or treated sewage into the rivers is further liable to contaminate their waters. The river waters must, therefore, be properly analysed and well treated before supplying to the public.

c) Storage Reservoirs as Surface sources of supplies

- A water supply scheme drawing water drawing water directly form a river or a stream may fail to satisfy the consumer demands during extremely low flows; while during high flows, it may again become difficult to carry out its operations due to devastating floods.
- A barrier in the form of a dam may, therefore, sometimes be constructed across the river, so as to form a pool of water on the upstream side of the barrier. This pool or artificial lake formed on the upstream side of the dam is known as the 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.
- Generally, multipurpose reservoirs are planned these days and operated so as to get optimum benefits. The subject of design and planning of dams and reservoirs is a big topic in itself, and is generally dealt under the subject of Irrigation.
- However, its salient features such as, Selection of dam site and types of dam ; Storage capacity of reservoirs, Reservoir sedimentation, Reservoir losses, etc. are, however being reproduced here.

INTAKES

Intakes are the structures used for admitting water from the surface sources (i.e., river, reservoir or lake), and conveying it further to the treatment plant. Generally, an intake is a masonry or concrete structure with an aim of providing relatively clean water, free from pollution, sand and objectionable floating material.

Selection of site

The following points should be considered in selecting a suitable site for the intake structure:

1. The site should be so selected that it may admit water even under worst condition of flow in the river, or under lowest possible water level in a lake or reservoir, if possible, intake should be located sufficiently inside the shore line.
2. Its site should be as near to the treatment work as possible.
3. It should be so located that it admits relatively pure water free from mud, sand or other floating materials. It should be located at a place protected from rapid currents.
4. It should be so located that it is free from the pollution. River intakes should be constructed well upstream of points of discharge of sewage and industrial wastes. If located near a city, it should be located to the upstream of the city so that water is not contaminated.
5. It should not interfere with river traffic, if any.

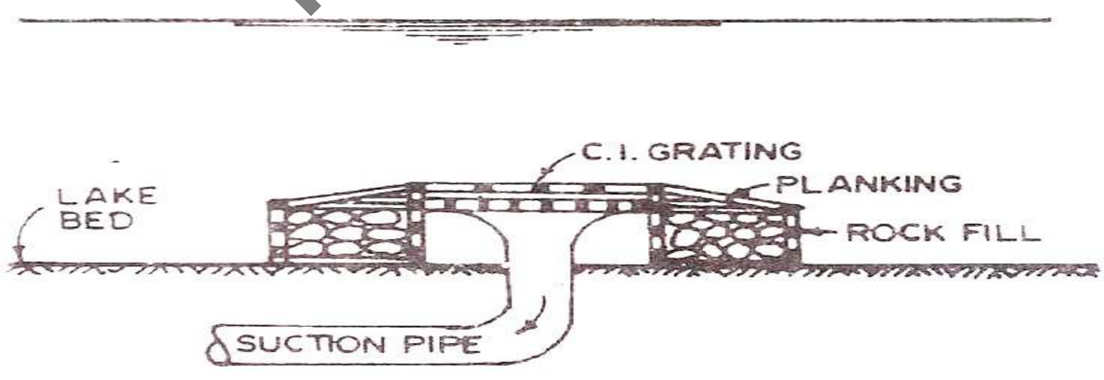
6. The intake should be so located that good foundation conditions are available and the possibility of scouring is the least.
7. Site should be so selected that its further expansion is possible.

Types of intake

a) Depending upon their position. (*Submerged and Exposed intake)*

1. Simple Submerged Intake

- *Submerged intake* is the one which is constructed entirely under water. Such an intake (Fig.a) is commonly used to obtain supply from a *lake.*
- A pipe is buried in a dredged channel across the bed of the river and the pipe is covered with soft earth. The remaining depth of the trench is covered with gravel and stone.
- Pipes are jointed with watertight joints and end with a bell-mouth, protected by a timber or concrete crib. The crib protects the conduit against damage and it is covered with rocks or rip-rap. The bell-mouth is covered with a coarse screen to eliminate the entry of submerged objects, debris, ice etc.
- Sometimes a fine screen is also provided to avoid the entry of fish and small floating objects. The conduit draws water from the source into a wet-well. Inspection of water-quality in the wet-well, shows the performance of the screens. From the wet-well, water is drawn by gravity or pumping to the treatment plant or distribution centre, as the case may be the area of the openings of the crib satisfy the entry velocity of not more than 15cm/s, to avoid the carrying of settleable particles into the intake pipe.
- The crib and the bell-mouth are submerged in water. This type of intake is cheap and there is no obstruction to navigation. They are therefore used for small water supply projects. But, there is a possibility of choking of the crib openings and bell-mouth. It is difficult to inspect and repair and allows draw water only from one level.



(Fig.a) ***Submerged intake***

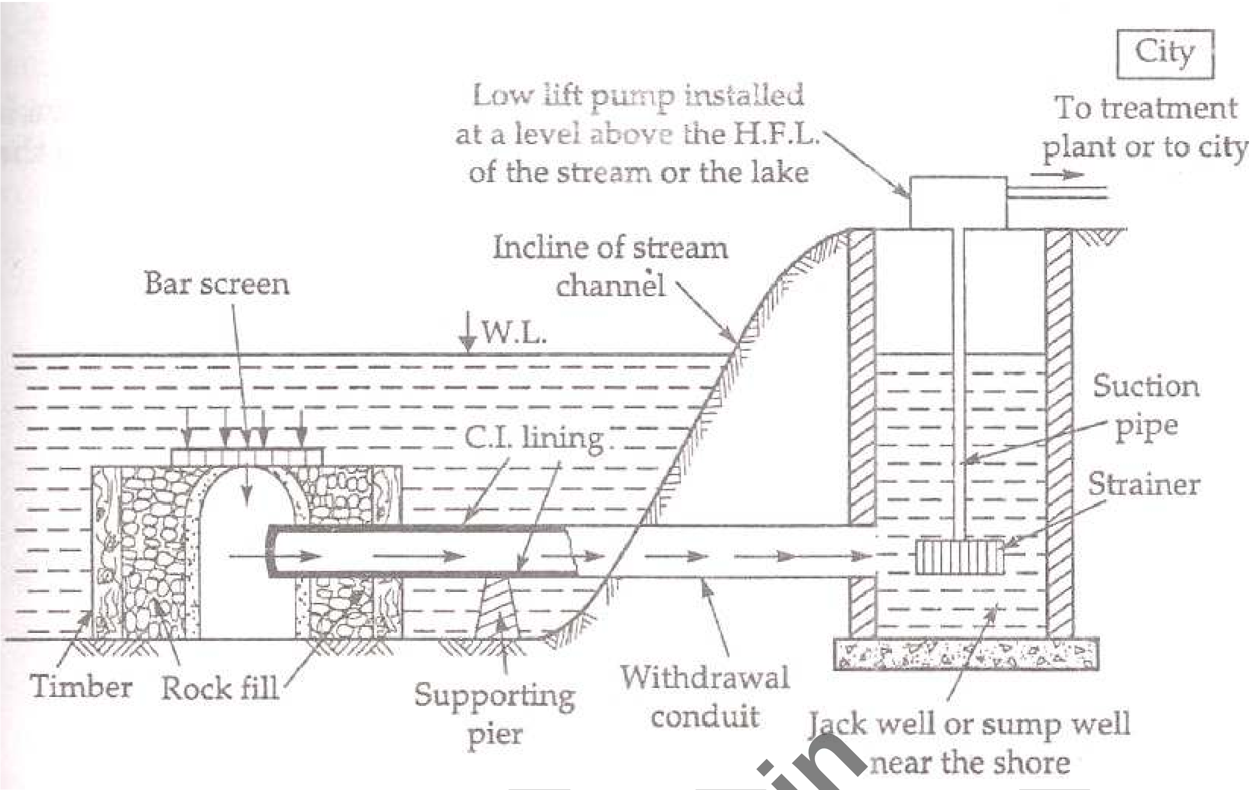


Fig.a-1: Simple Concrete block- *Submerged intake*

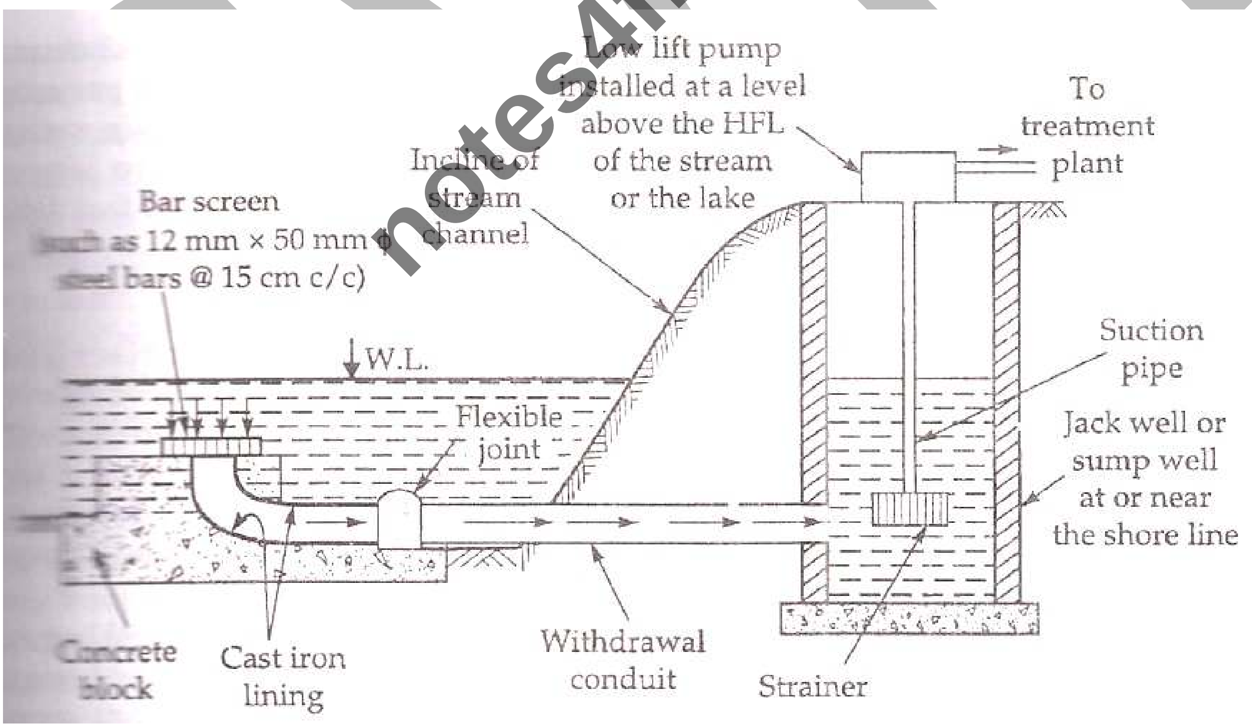
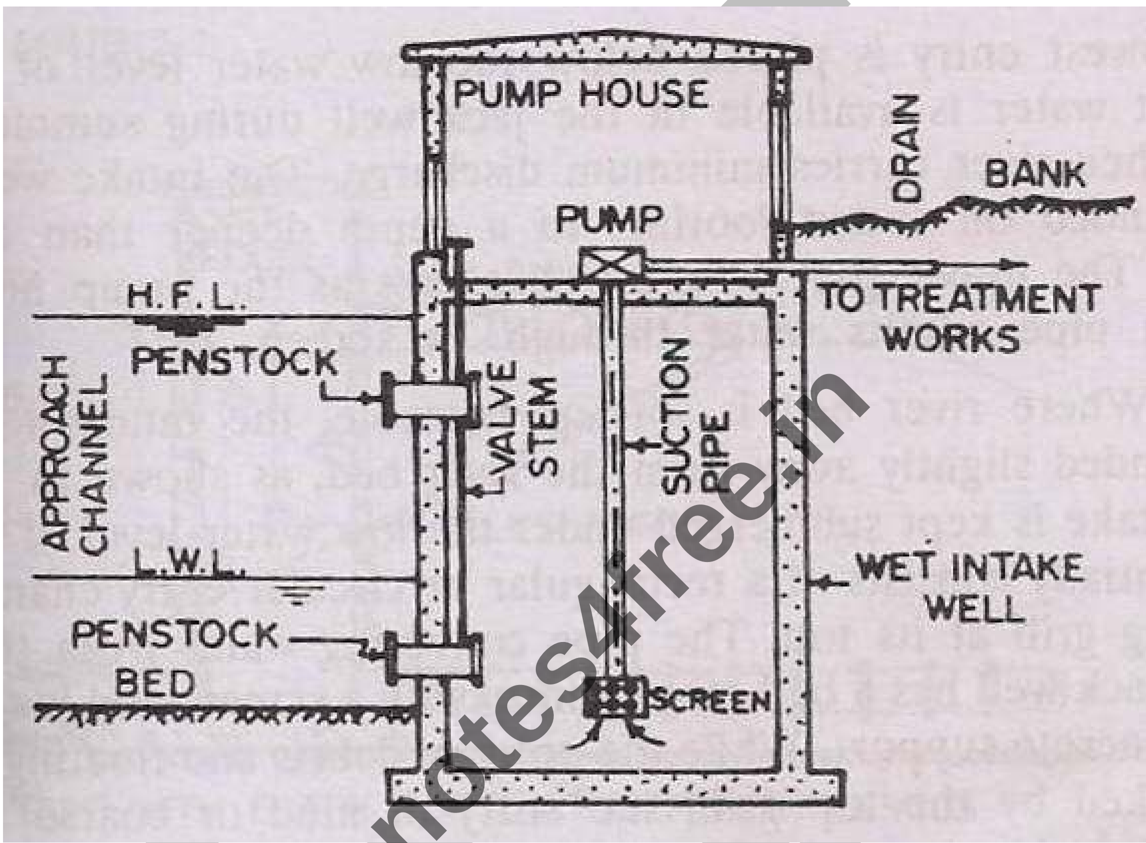


Fig.a-2: Rock filled timber crib- *Submerged intake*

2. Exposed intake

- *Exposed intake* is in the form of a well or tower constructed near the bank of a river, or in some cases even away from the river bank.
- This type of intake may be used for tapping water from reservoirs, lakes or rivers. Exposed intakes are more common due to ease in its operation **(Fig b).** They are located (a) in the dams of reservoirs as a part of the dam, or (b) on the banks or rivers and lakes.
- An exposed intake can be called as "gate-house" or "valve-tower" in the case of a reservoir. It is easier to inspect and operate then a submerged intake. Water can be drawn at any desired level.



(Fig b). ***Exposed intake***

(b) Intake towers

3. Wet intake

- *Wet intake* is that type of intake tower in which the water level is practically the same as the water level of the sources of supply. Such an intake is sometimes known as *jack well* and is most commonly used.
- A typical section of a wet intake tower is shown in **(Fig.c).** It may consist of a concrete circular shell filled with water up to the reservoir level and has a vertical inside shaft which is connected to the withdrawal pipe. The withdrawal may be taken directly to the treatment plant in case no lift is required (such as in reservoir) or to the sump well in case a low lift is required (such as in case of a river).

- Openings are made into the outer concrete shell, as well as, into the inside shaft as shown. 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 without conduit may be taken to pump house for lift, if the water treatment is at higher elevation , or may be taken directly to WTP if it is situated at lower elevation.

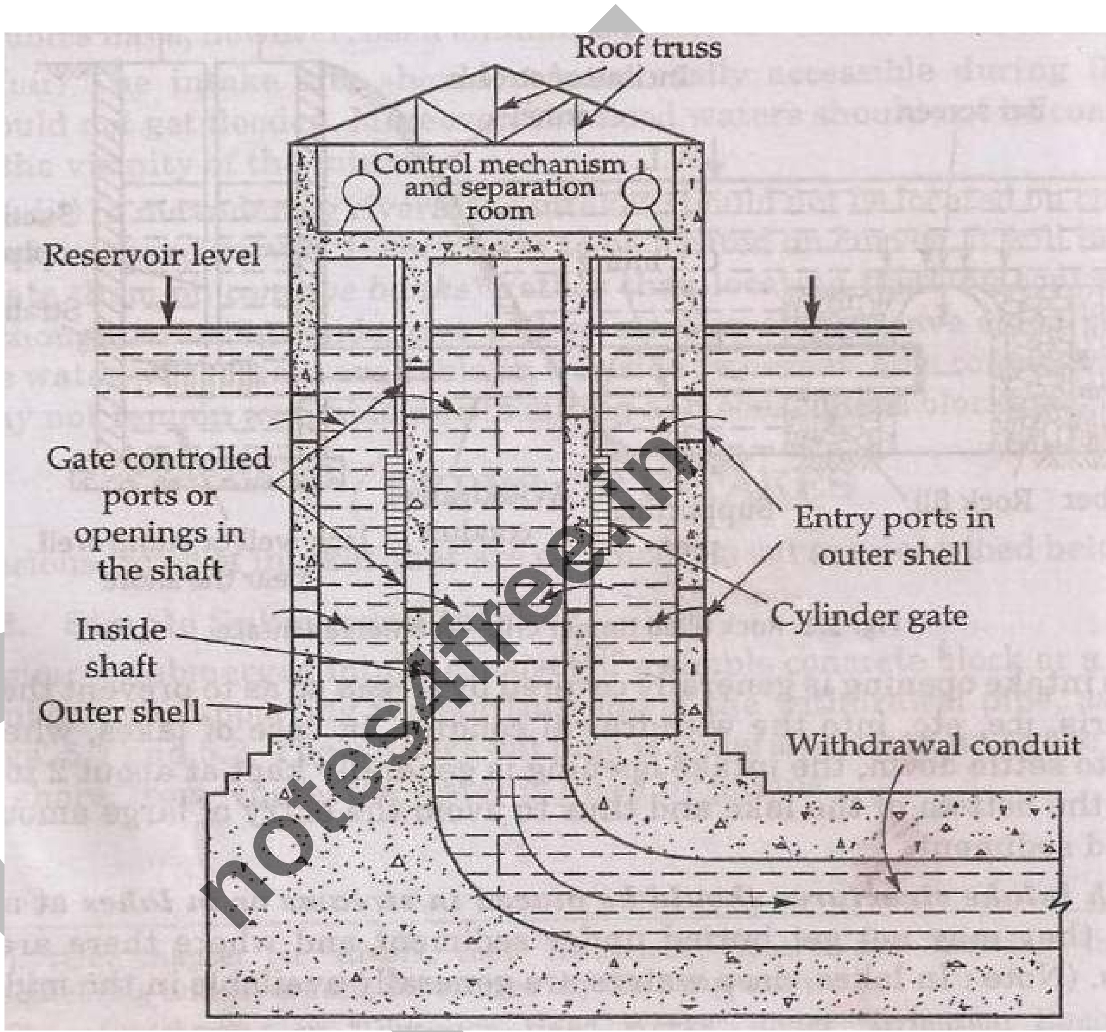


Fig.c : Wet intake

4. Dry intake.

- In the case of dry intake, Water enter enters through entry port directly into the conveying pipes.
- Whereas the entry ports are closed, a dry intake tower will be subjected to additional buoyant forces and hence, must be of heavier construction than the wet intake owners. However, the dry intake towers are useful and beneficial in the sense that water can be withdrawn from any selected level of the reservoir by opening the port at that level.
- The essential difference between a dry intake tower and a wet intake tower is that, whereas in a wet intake tower, the water enters from the entry ports into the tower and then it enters into the conduit pipe through separate gate controlled openings; in a dry intake tower, the water is directly drawn into the withdrawal conduit through the gated entry ports, as shown in (Fig.d).

- A dry intake tower will, therefore, have no water inside the tower if its gates are closed, whereas the wet intake tower will be full of water even if its gates are closed.

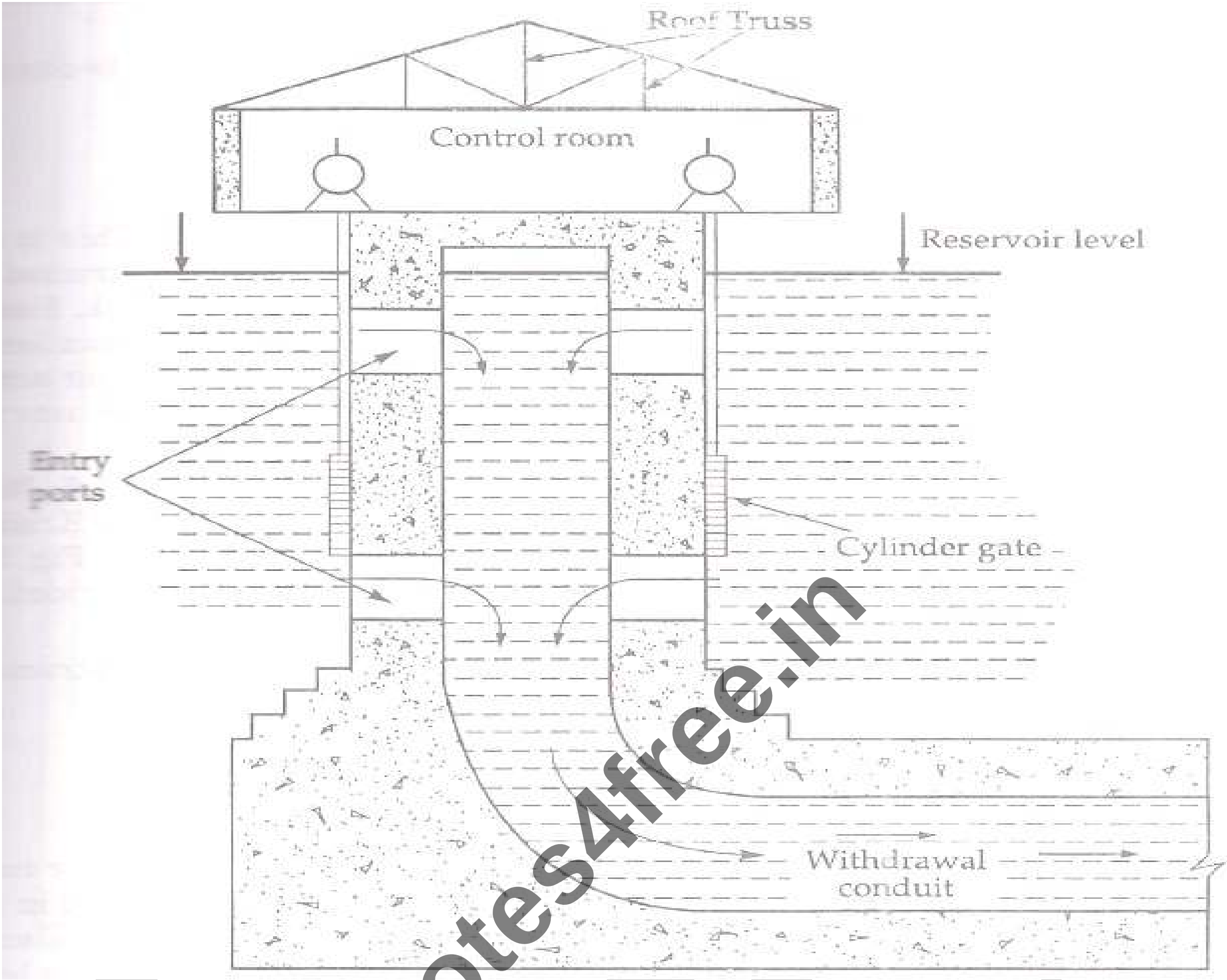


Fig.d : Dry intake

5. River Intakes

- A river intake is located to the upstream of the city so that pollution is minimized. They are either located sufficiently inside the river so that demands of water are met within all the seasons of the year, or they may be located near the river bank where a sufficient depth of water is available. Sometimes, an approach channel is constructed and water is led to the intake tower.
- If the water level in the river is low, a weir may be constructed across it to raise the water level and divert it to the intake tower. (Fig.1) shows a wet type intake well founded on river bed.
- The intake tower permits entry of water through several entry ports located at various levels to cope with the fluctuations in the water level during different seasons. These entry ports are sometimes known as penstocks and are provided with suitable designed screens to exclude debris and floating material from entry.

- The entry ports contain valves which can be operated from the upper part of the well. The lowest entry is placed below the low water level of the river so that water is available in the jack well during summer season also when river carries minimum discharge.
- The intake well should be founded on sound footing, to the depth deeper than the scour depth. The upper part of the well serves as the pump house. The suction pipe admits water through a screen.

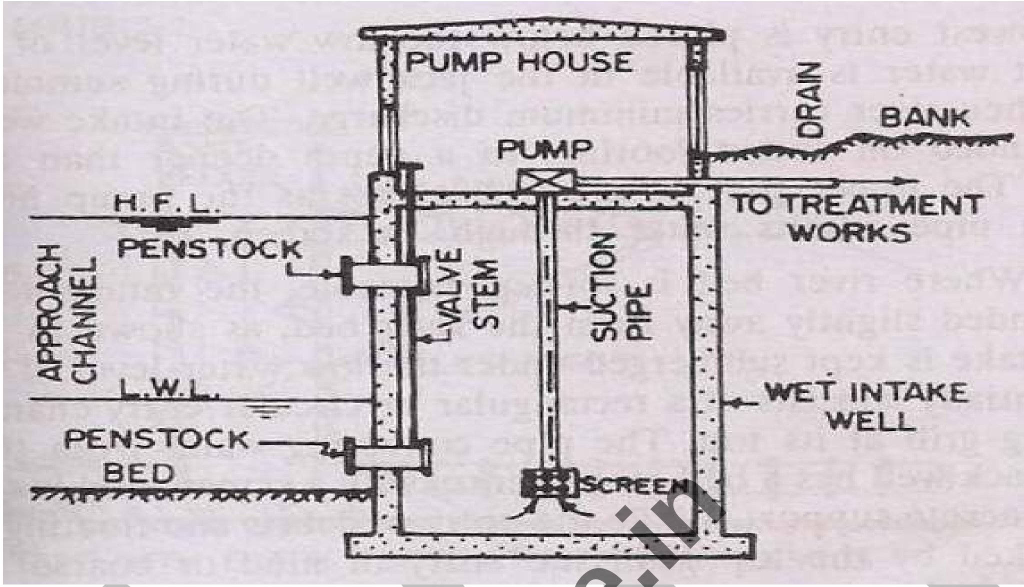


Fig:1

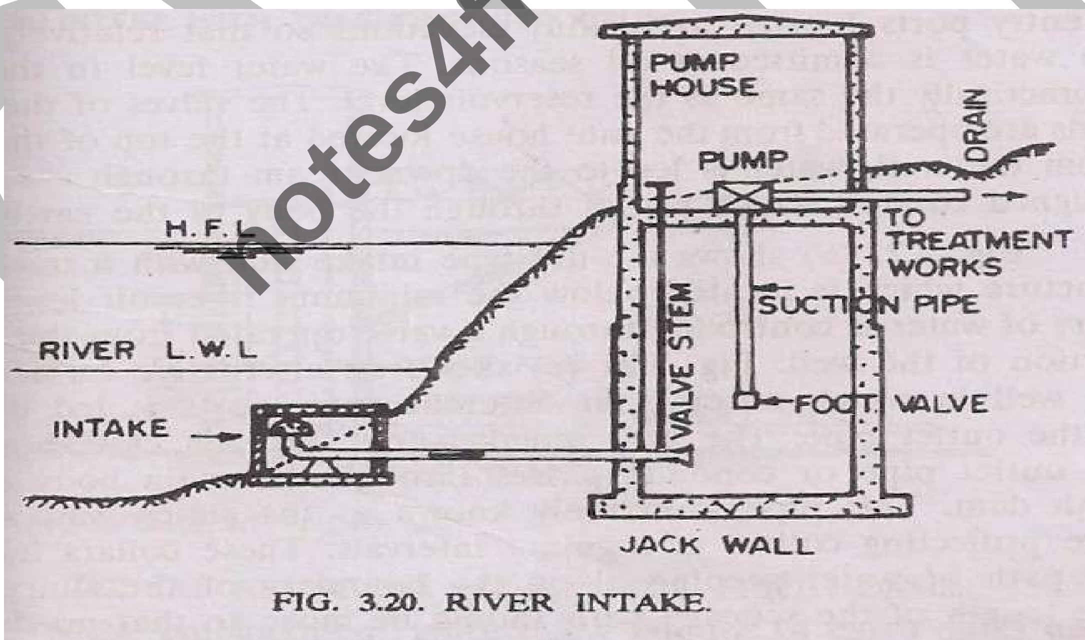


FIG. 3.20. RIVER INTAKE.

Fig:2

Fig:1 and 2 – River Intakes

6. Lake Intake

- Lake intakes are similar to reservoir intakes if the depth to water near the banks is reasonable. If however, the depth of the water near the banks is shallow, and greater depth is available only at its centre, a submerged intake is provided, as shown in (Fig.f).
- Submerged intakes are constructed as cribs or bell mouths. The cribs are made of heavy timber frame work which is partly or wholly filled with rip-rap to protect the intake conduit against damage by waves etc. the top of the crib is covered with cast iron or mesh grating.

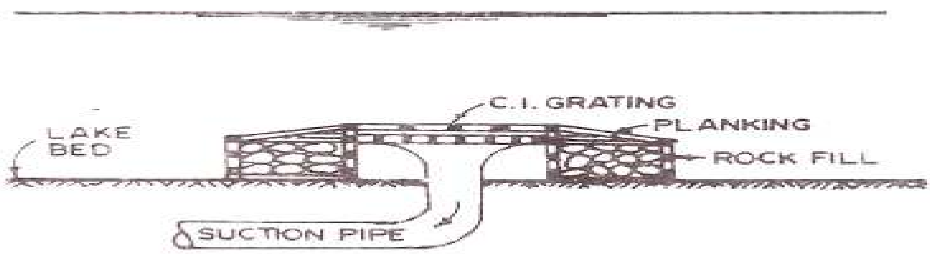


Fig:f – Lake Intake

7. Canal Intake

- Sometimes, the source of water supply to a small town may be an irrigation canal passing near the town. The canal intake is shown is **(Fig. g).**
- It essentially consists of concrete or masonry intake chamber of rectangular shape, admitting water through a coarse screen. A fine screen is provided over the bell mouth entry of the outlet pipe. The bell mouth entry is located below the expected low water level in the canal.
- Water may flow from outlet pipe under gravity if the filter house is situated at a lower elevation. Otherwise, the outlet pipe may serve as suction pipe, and the pump house may be located on or near the canal bank.
- The intake chamber is so constructed that it does not offer any appreciable resistance to normal flow in the canal. The flow velocity through the outlet conduit is generally kept at about 1.5m/Sec, and this helps in determining the area and dia of the withdrawal conduit.

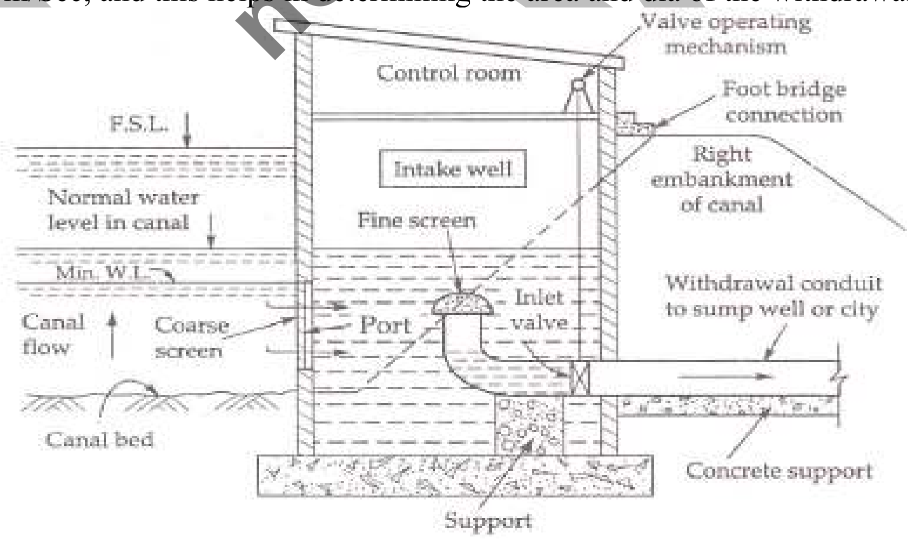


Fig:g – Canal Intake

8. Reservoir intake:

- When the floe in the river is not guaranteed throughout the year, a dam is constructed across it to store water in the reservoir so formed. These intakes are constructed near the toe of the dam where maximum depth is obtained usually at upstreams.
- This is also known as a *valve tower* (fig.h) it is a circular chamber of masonry or concrete with its flow sufficiently below the low water level in the reservoir, so they water can be drawn from the reservoir even from the lowest level.
- In masonry dams, it is built as a part of the dam. Intake ports or penstocks with screens are provided at intervals of one to two metres from the high water level to the low water level, so that clean water can be drawn from one or more penstocks, for various fluctuations of the level in the reservoirs.
- All the penstocks are connected to a vertical down take pipe, which is connected to the intake outlet conduit, at the bottom of the well. The outlet conduit can be controlled by a gate valve/ Stop valve, which can be operated from the top RCC cover of the intake-well.
- Penstocks are also provided with control valves. A foot-bridge is provided between the top of the dam and the value tower, for approach. A steel ladder is provided at the bottom of the well, so that inspecting personnel can enter it.
- The lowest penstock is located below the low water level, and the highest is below the high water level. A cabin is provided over the well, for the protection of all control valves and also as a shelter for personnel.

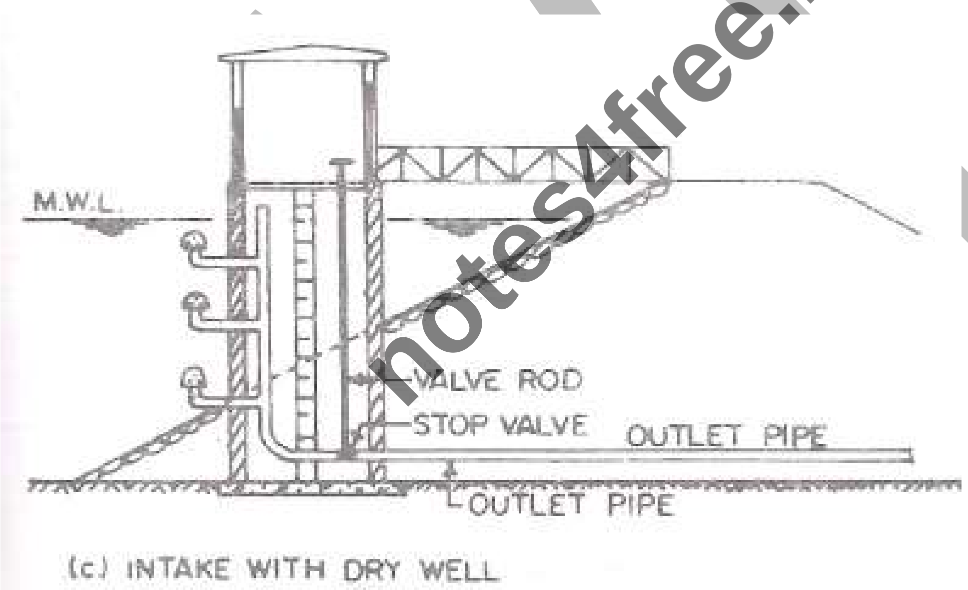


Fig:h – Reservoir Intake

PUMPS

A pump is a device which converts mechanical energy into hydraulic energy. It lifts water form a lower to a higher level and delivers it at high pressure. Pumps are employed in water supply projects at various stages.

Pumps are needed for the following purpose

1. To lift raw water from wells.
2. To deliver treated water to the consumer at desired pressure.
3. To supply pressured water for fire hydrants.
4. To boost up pressure in the water mains.
5. To fill elevated overhead tanks for distribution of water.
6. To back-wash filters.
7. To de-water tanks, basins, sumps, etc.
8. To pump chemical solutions needed for the treatment of water.

THE SELECTION OF TYPE OF PUMP DEPENDS ON THE FOLLOWING FACTORS

1. Capacity of pumps .
2. Initial costs.
3. Maintenance cost, including depreciation.
4. Cost of energy and labor.
5. Efficiency of pumps.
6. Space required for locating of pumps.
7. Suction and delivery heads.
8. Nature of liquid to be pumped.
9. Total quantity of water
10. Type of service-intermittent or continuous
11. Type of power available.
12. Variation in the rate of pumping and pumping head.

CLASSIFICATION OF PUMPS

a) Based on the principle of operation, pumps may be classified as follows.

1. Displacement pumps (reciprocation, rotary)
2. Velocity pumps (centrifugal, turbine and jet pumps)
3. Buoyancy pumps (air lift pumps)
4. Impulse pumps (hydraulic rams)

b) Based on the type of service, pumps are classified as follows.

1. Deep well pumps
2. High lift pumps
3. Low lift pumps
4. Booster pumps
5. Stand-by pumps

c) Based on the power required classified as follows.

The various sources of power for pumps are the following.

1. **Steam engines:** They consume a lot of fuel and there is loss of energy. They are outdated and used only for large installations where fuel is cheaply available.
2. **Diesel engines:** Theses are not used for centrifugal pumps, since the speeds are not sufficient. They require more initial cost and skilled personnel. They are less reliable and make a lot of noise during working.
3. **Gasoline engines:** They are costly and are not used for low heads. They need stand-by pumps.
4. **Electric driven pump:** They are suitable for medium and small plants. Their initial cost is low and they are compact in design. They run smoothly and occupy less space. But in case of failure of power supply, the whole water supply comes to a standstill, so that stand-by power-lines always need to be provided.

a) Based on the principle of operation, pumps may be classified as follows.

1) Displacement pumps

These work on the principle of mechanical induction of a vacuum in a chamber so that water can be drawn into it. Then this water is mechanically displaced and delivered through a pipe. Displacement pumps are of two types,

(i) Reciprocating pumps
(ii) Rotary pumps

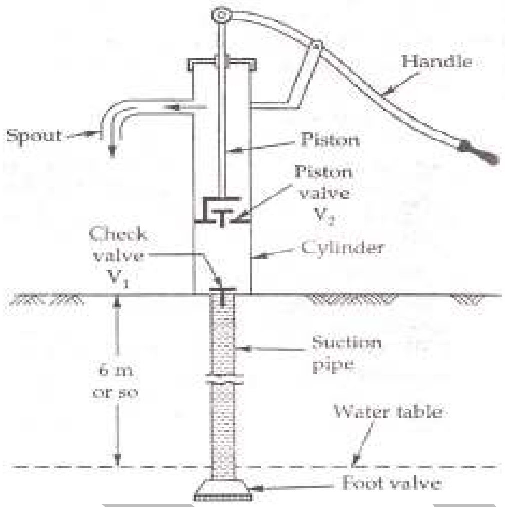


Fig: Hand operated reciprocating pump.

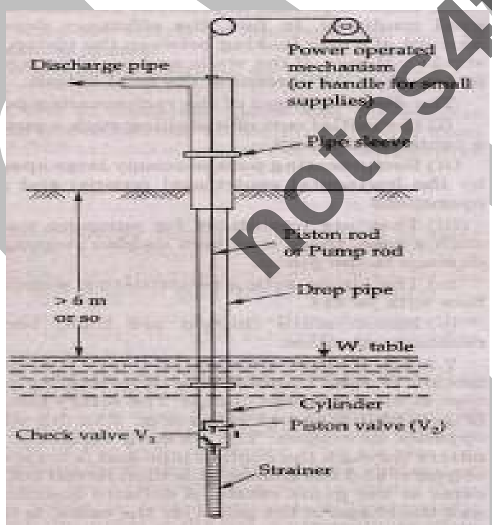


Fig: Deep well reciprocating pump.

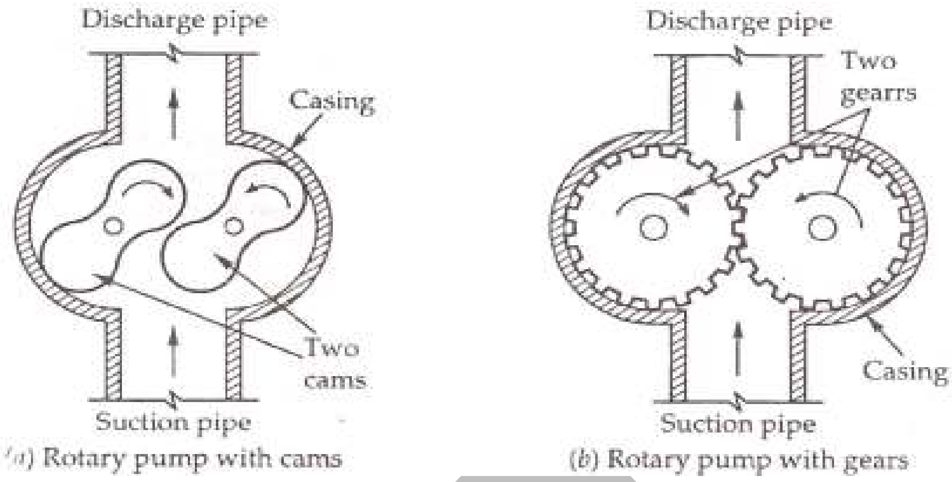


Fig: Deep well Rotary pump.

Advantages

1. They do not require any printing
2. They require no valves
3. Rate of flow is uniform.

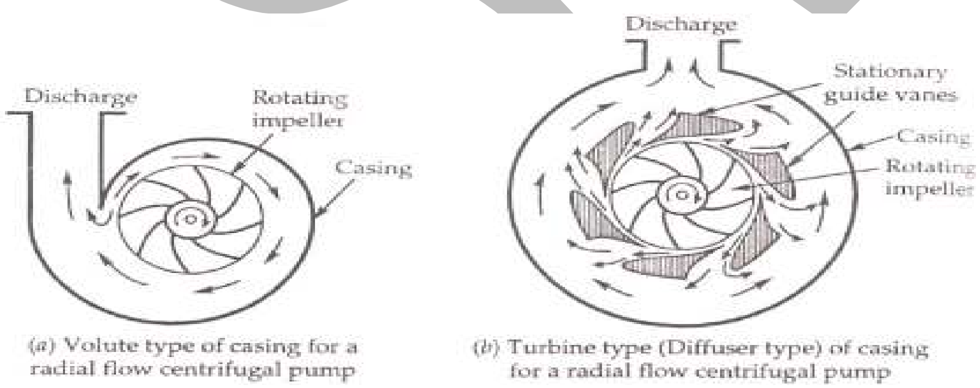
Disadvantages

1. The initial cost of these pumps is high
2. Gears need to be replaced frequently
3. They cannot pump water containing silt and sand.

2) Centrifugal pumps

In centrifugal pumps, water entering the pump-casing is made to revolve at high speed by means of an impeller. The impeller induces a centrifugal force, which pushes the water to the periphery and to the delivery pip. Centrifugal pumps can be classified into two types,

1. Volute type centrifugal pump
2. Turbine type centrifugal pump.



(Fig. 4.12)- Centrifugal pumps

Advantages

1. They are high speed pumps and can be directly connected to the electric motor.
2. Discharge and power requirements are uniform for a head

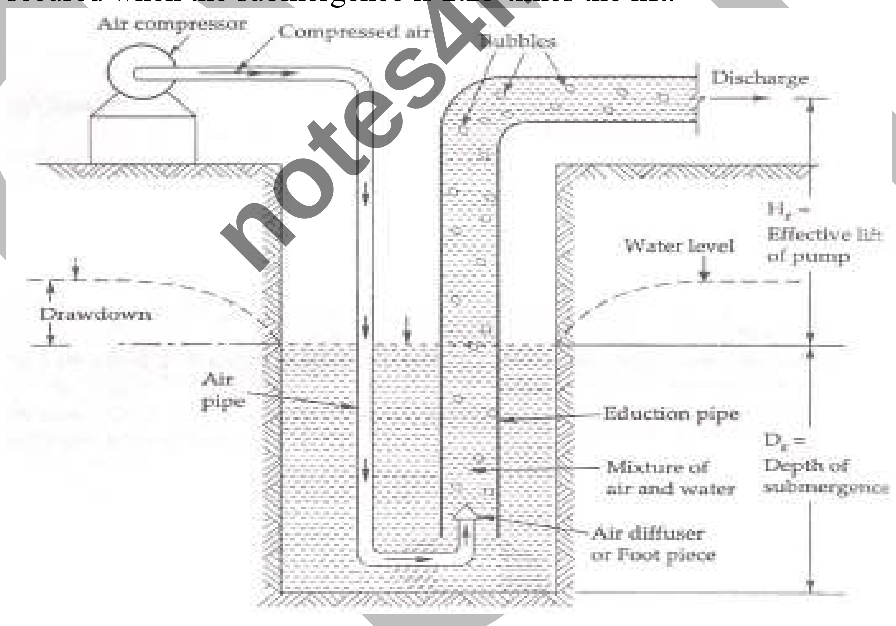
3. They are compact in design and occupy less floor space
4. Initial cost, as well as maintenance costs are less
5. Working is simple and reliable
6. They are easier to start than other pumps
7. They do not have valves, and have few moving parts
8. They can be used for water containing grit and sand
9. Elaborate foundation is not required
10. Discharge can be varied and shut whenever necessary.

Disadvantages

1. For high lifts, efficiency is less
2. Suction head is limited to7.0 m
3. Priming it required before starting.

1) Air lift pumps

- An air lift pump is an apparatus for raising water from wells through discharge or reduction pipes (Fig. 4.13). These pipes are extended from ground level into the well to a proposed depth.
- Compressed air is forced with an air pipe to the bottom into a reduction pipe which is enclosed in a casing pipe. The mixture of air and water at the bottom of the pipe has a low specific gravity. The air-water mixture rises through the education pipe and moves up-ward. The air bubbles continue to expand until the outlet is reached and atmospheric pressure prevails. The efficiency of the pump depends on the submergence. Maximum efficiency is secured when the submergence is 2.25 times the lift.



(Fig. 4.12)- Air lift pumps

Advantages

1. They are cheap, reliable and simple to operate
2. There are no moving parts inside water, so they can be used for acid and alkaline waters as well as water with sand or grit
3. Discharge can be increased by using more compressed air
4. Greater the air lift capacity, the greater its efficiency.

Disadvantages

1. To have greater depth of submergence, the well needs to the deep, leading to higher costs
2. Efficiency is relatively low
3. Flow may not be continuous
4. They are not very flexible, since they cannot cope up with variations in demand.

2) Miscellaneous pumps

Hydraulic ram: A hydraulic ram is a type of pump where 'the energy of water flowing in a pipe' is used to raise a small quantity of water to a higher elevation. Water enters the ram through an inlet pipe. When the ram is full, the waste valve opens sand the delivery valve closes. Water from the waste valve opens and delivery valve closes. Water from the waste valve flows out and water attains maximum velocity in the ram. Now the waster valve closes suddenly and the delivery valve opens. Water from the ram enters the air chamber and goes to the outlet through the delivery pipe. After some time, pressure in the ram falls, the delivery valve closes, the waster valve opens, and the cycle repeats itself. There may be 50 – 200 cycles/minute depending on the design of the ram. Hydraulic rams may be used for small water supplies. Some are,

1) Jet pumps
2) Hydraulic Ram

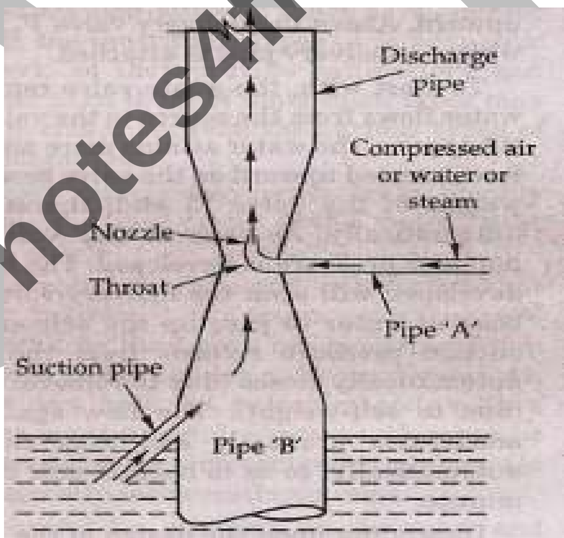
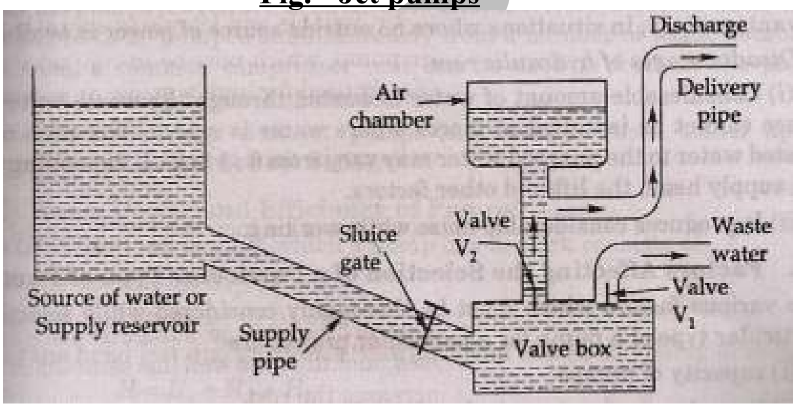


Fig. - Jet pumps



Prof. SAKALA. B.T, Department of Civil Engineering, SVIT, Bangalore-64.

Fig. - Hydraulic Ram pumps

Advantages

d) Working is simple and no attention is required
e) It is durable
f) It is cheap and does not require fuel for working

Disadvantages

1. There is considerable wastage of water through waste valves
2. It creates lot of noise while working.

3. Based on the type of service, pumps are classified as follows.

1) Deep well pumps: these are used to pump water from tube wells. The pump essentially consists of two parts.

(i) Driving motor, head assembly and delivery connection
(ii) Pumping unit installed under the head assembly to depth of about 24 to 30 m, below round level.

2) High lift pumps: They are sued for lifting water for high heads.
3) Low lift pumps: They are used for low heads.
4) Booster pumps: Booster pumps serve low purposes:

1. To increase the carrying capacity of a main, so as to avoid enlargement of diameter
2. To increase the head in the main, where it is insufficient for supply.

Booster pumps work during times of maximum water demand. When the booster pump works, the slope of the hydraulic gradient in the pipe steepens, thereby increasing the discharge and pressure head in it, Reflux valve and check valve are used in the boostered main. Booster pumps are also used to lift water to multistoried buildings.

PIPES

Pipe is a circular closed conduit through which the water may flow either under gravity or under pressure. When pipes do not run full, they run under gravity, such as in sewer lines. However, in supply, pipes mostly run under pressure. Pipes may be made of the following materials:

1. Cast iron.
2. Wrought iron.
3. Steel.
4. Galvanized iron.
5. Cement concrete.
6. Asbestos cement.
7. Plastic.
8. copper.

9. Woods.

Economical Diameter of the Pumping Mains

- As pointed out in the previous chapter, the diameter of a pipe can be reduced (for passing a certain fixed discharge) by increasing the flow velocity through the pipe. But, however, the increased velocity will lead to higher frictional head loss, and thus increased cost of pumping.
- Hence, although the dia and the cost of pipe can be reduced by choosing a higher flow velocity, the horse power of the pump required will increase, thus increasing the cost of pumping. For optimum conditions, we must choose such a diameter, the minimum.
- The diameter which provides such optimum conditions is known as the **economical diameter** of the pipe.
- Hence, if the diameter chosen is less than the economical diameter, the cost of pipe will be less, but the head loss will be high and the cost of pumping shall be much more than the resultant saving in the pipe cost. Similarly, if the diameter chosen is more than the economical dia, the cost of pumping will be less but the increase in the cost of pipe will be much more than the resultant saving obtained in the cost of pumping.

An empirical formula given by Lea, connecting the dia and the discharge, which is commonly used in practice is given as:

$$D = 0.97 \text{ to } 1.22\sqrt{Q}$$

Where D = economical dia in meters.

Q = discharge to be pumped in cumecs.

This relationship gives optimum flow velocity varying (between 1.35 to 0.8 m/sec)

For a rigorous analysis, total cost of pipe and pumping should be worked out at different assumed velocities(between 0.8 to 1.8) and a graph plotted between the yearly cost and the size of the pipe **(Fig. a).**

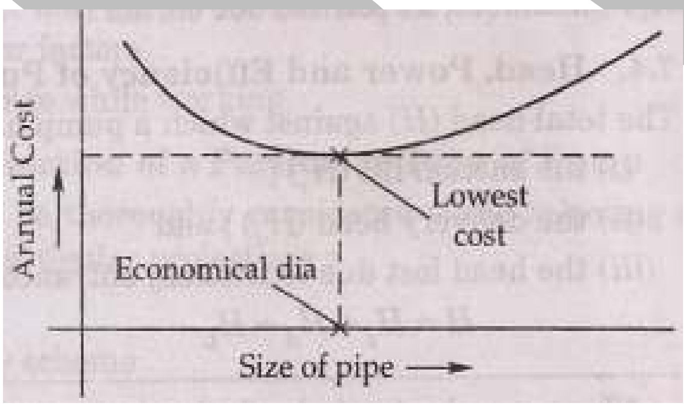


Fig.(a).

The economical size is the one which gives the least cost, and thus selected by inspection, as shown in **Fig. (a).**

Horse power of the pump motor. The power of a motor is given by the equation

Power=wQ.H/ η kW,

where 1HP = 0.735 kW

then, HP= wQ.H/0.735 η

Where Q= Discharge to be delivered in m^3/s

H= Total lift, i.e. the head against which the motor has to work, in m

w= Unit weight of water in k N/m^3= 9.81 kN/m^3

η = Efficiency of the pump set, and is generally taken as 65% (i.e. 0.65)

Pipe Appurtenances

In order to isolate and drain the pipe line sections for tests, inspections, cleaning and repairs; a number of appurtenances such as gates, valves, manholes, insulation joints, expansion joints, anchorages, etc., are provided at various suitable places along the pipe lines, as described below.

Gates and Valves in Pipe Lines. A large number of different types of valves are required for the proper functioning of the pipe line, as described below and shown in Fig.(b)

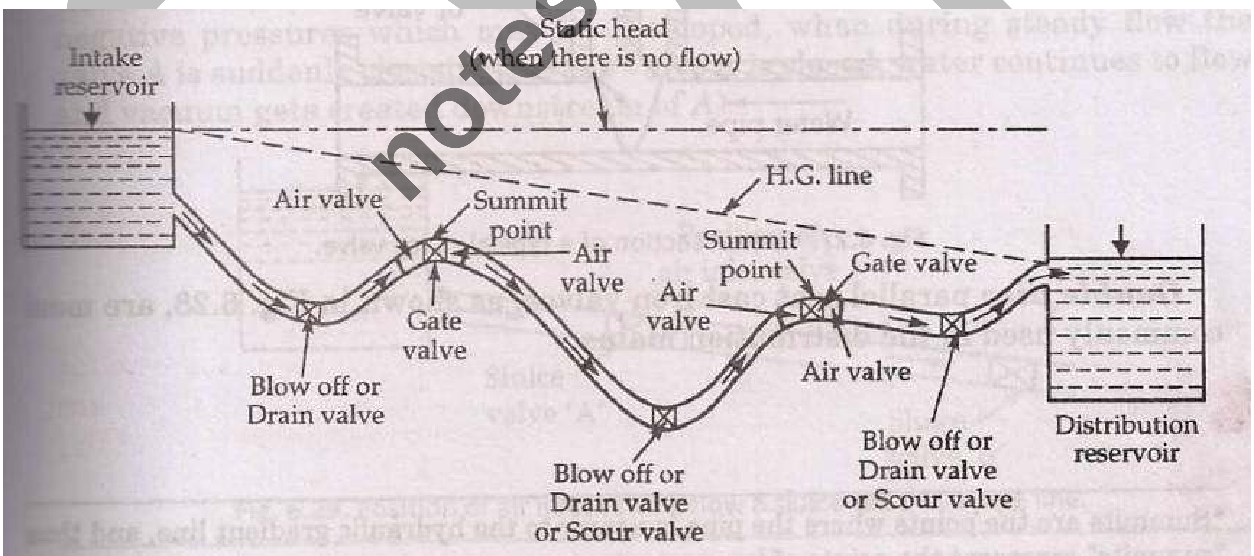


Fig.(b)-Profile of the pressure pipe showing the location of the gates and valves

(a) Gate valves or Sluice valves.

- Gates or sluice valves are used to regulate the flow of water through the pipes. They are similar to gate valves used in dams but are not so large.
- In large pipe lines, bringing water from the source to the city, they are generally located along the pipe line at intervals of about 3 to 5 kilometers, so as to divide the pipe line into different sections.

Prof. SAKALA. B.T, Department of Civil Engineering, SVIT, Bangalore-64.

- Thus, during repairs, only one section can be cut off at a time, by closing the gate at both ends of the section.
- The gate valves are usually placed at the summits (Fig. b) of the pressure conduits, because when so placed at these points of low pressures, they can be of cheaper and less stronger materials, and also, they can be operated easily with less force.
- For economy. In large diameter pipes, valves of smaller diameter than the pipe itself are generally used.
- However, the saving in the valves cost must be balanced against the increased head loss through the valve (because head loss through the valve increase with the reduction in the size of its opening because of higher velocity of flow) including the extra loss in contraction and re-expansion.

The most commonly used type of a gate valve or a sluice valve is shown in Fig.c.

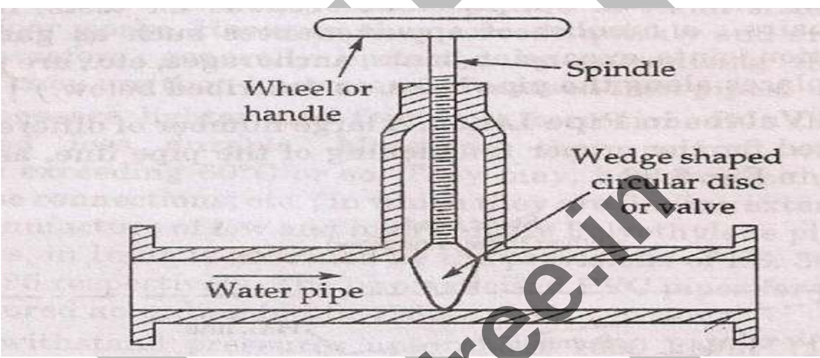
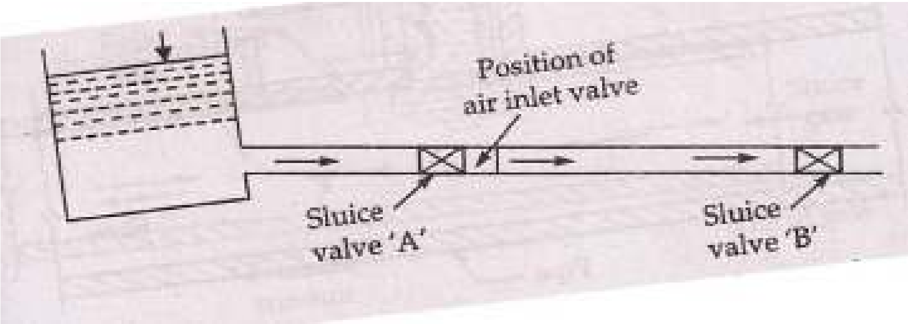


Fig.c- Gate valves or Sluice valves

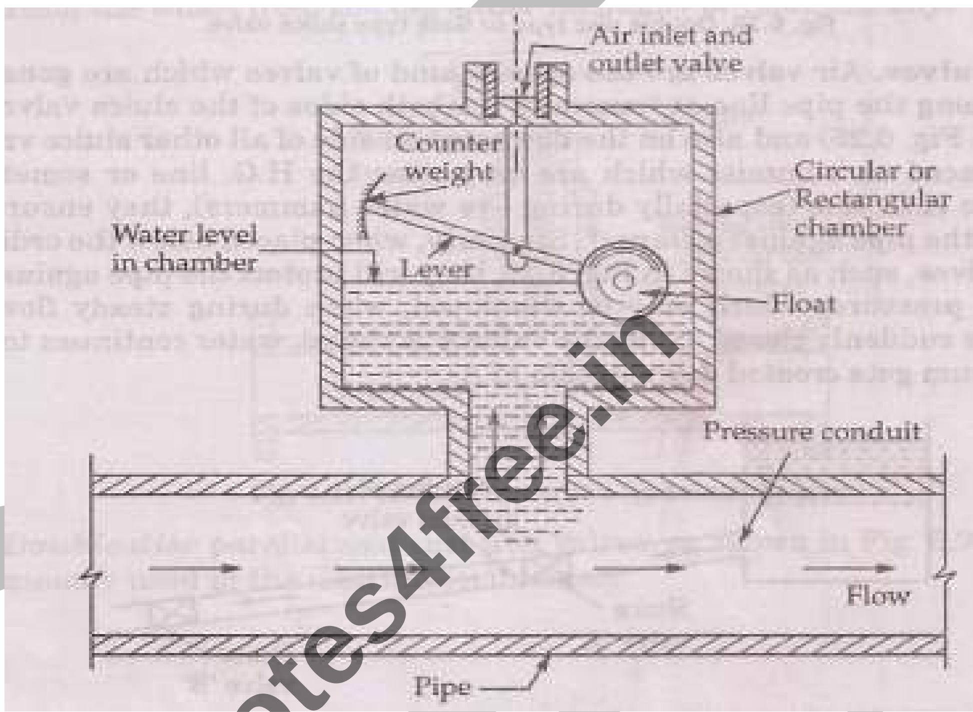
- The valve is made of cast iron with brass, bonze or stainless steel mountings. The ends of the valve are properly jointed on both sides of the pipe lengths, by suitable standard joints (described earlier).

(b)**Air valves.**

- Air valves are the special kind of valves which are generally placed along the pipe line at "summits" on both sides of the sluice valves (as shown in Fig. a)and also on the downstream side of all other sluice valves.
- When placed on summits which are very near the H.G. line or sometimes above the H.G. lin (especially during –ve water hammers), they ensure the safety of the pipe against collapse.
- Similarly, when placed below the ordinary sluice valves, such as shown in (Fig. d), they will protect the pipe against the negative pressures which may be developed, when during steady flow the valve A is suddenly closed. (because as the valve A is closed, water continues to flow and vacuum gets created downstream of A).



(Fig. d) – Position of air inlet valve below a sluice valve in a pipe line.



(Fig.) – Vertical section of poppet type Air valves

(b) Blow off valves or Drain valves or Scour valves.

- In order to remove the entire water from within a pipe (after closing the supply), small gated off takes are provided at low points, as shown in (Fig.a).
- These valves are known as blow off valves or drain valves or scour valves. These valves, are necessary at low level points for completely emptying the pipe for inspection, repairs, etc. when opened, water comes out of these valves quickly under gravity and they are made to discharge water into some natural drainage channel or into a sump from which the water can be pumped out.
- It may, however, be stressed that here should be no direct connection between the valve and the sewer or the drain, so as to avoid the possibility of pollution travelling into the water pipe. Fore safety, two drain valves are generally placed in series. So as to reduce the chances of such pollution reaching the water in conduit.

(d)**Pressure-relief valves.**

- Water hammer pressures in pressure pipes can be reduced by using pressure relief valves. Such a valve is adjusted to open out automatically as soon as the pressure in the pipe exceeds a certain fixed predetermined value.
- Due to the opening of this valve, certain water will get out of the pipe, and thus, reducing the pressure in the pipe. As soon as the water hammer pressure reduces, and the pressure in the pipe falls up to the fixed value, the valve will closed automatically.
- Such type of valves are useful on small pipelines, where the escape of a relatively smaller amount of water will alleviate water hammer pressures. A simple sketch of a pressure relief valve is shown in **Fig.e**.

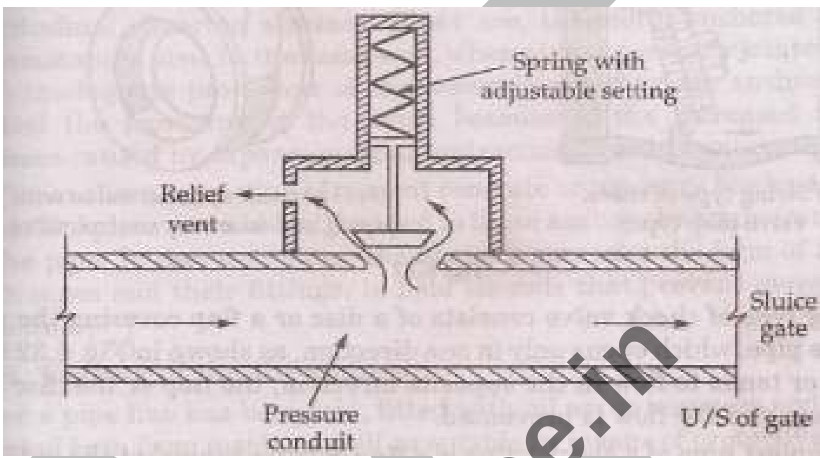
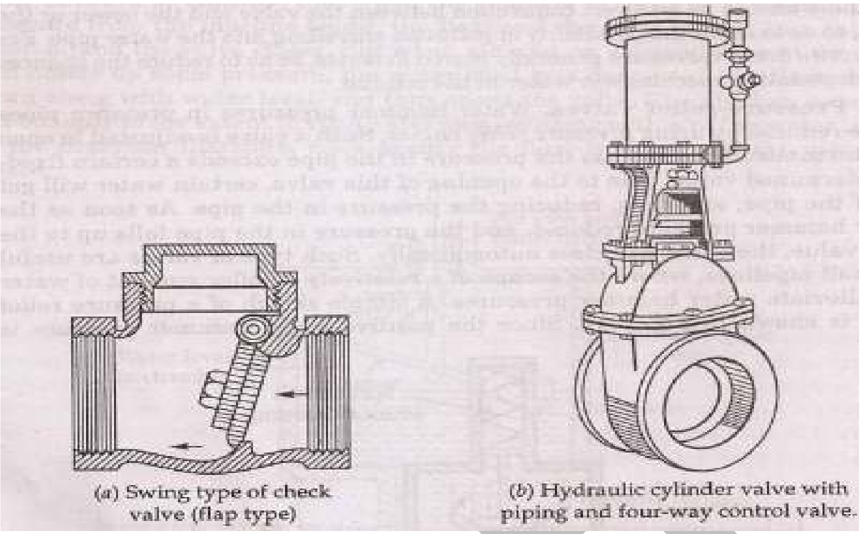


Fig.e - Pressure-relief valves.

- Since the positive water hammer pressure is developed due to the sudden closure of a sluice valve on its upstream side, such relief valves may be provide on the upstream side of the sluice valves.
- Even if not provide specifically for water hammer, such valves are often placed along the pipe line at suitable intervals (especially at low points where the pressures are high), so as to function during emergencies, when pressure rises in the pipe above the design value, and thus to help protecting the pipe joints from getting loosened or the pipes from getting **burst.**

(e) check valves or Reflux valves.

- Check valves are also sometimes called **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 or pumped water, when the pump is stopped.
- Check valves are also installed on pump discharges to reduce water hammer forces on the pump.
- Such a valve may be a simple swing check or ball devices **(Fig. f)** in small lines ; but in large installations, they should be designed to close slowly, usually with discharge of some water through a bypass.


(a) Swing type of check valve (flap type)
(b) Hydraulic cylinder valve with piping and four-way control valve.

<u>Fig. f - check valves or Reflux valves.</u>

2) Manholes.

- Manholes are provided at suitable intervals along he pipe line, so as the help its laying, and to serve for inspections and repairs. They are generally provided on large pipe lines bringing water from the source to the city at intervals of about 300 to 600 meters or so.
- They are usually provided in case of steel, hume steel, or R.C.C. pipes (which are commonly used for conveyance of water from the source to the city) and are less common on cast iron pipes.

3) Insulation Joints.

- Insulation joins are provided along the pipe lines at suitable intervals, so as to insulate the pipe against the flow of stray electric currents, and thus, to check electrolysis.
- Rubber gaskets or rings can be provided as insulators, in between the pipe lengths, so as to prevent the flow of electric current between them. Similarly, sometimes, sufficient length of the pipe is covered with rubber covering, so as to provide appreciable resistance to the lfow of current.

4) Anchorages.

- As pointed out earlier, the pipes try to pull apart and get out of the alignment at bends and other points of unbalanced pressures.
- At such places, the forces exerted on the joints due to longitudinal shearing stresses caused by these unbalanced pressures are enormous, and the joints may get loosened, ultimately leading to excessive leakage or failure of the pipe.
- In all such circumstances, in order to prevent the pipes from pulling apart, pipes are anchored by firmly embedding these portions in massive blocks of concrete or masonry, which absorbs the side thrusts.
- Similarly, when pipes are laid on steep slopes, they try to slip and thereby pull apart, and the resistance of their joints may be insufficient to balance the longitudinal shearing stresses. Pipes are, therefore, anchored under such circumstances also. The anchors consisting of cement concrete or masonry blocks are generally used.