(Prepared By: Ms. Promila , Assistant Professor , MED)

CHAPTER 1
Introduction

INTRODUCTION

The word 'Hydraulics' has been derived from a Greek word 'Hudour' which means water. Hydraulics is that branch of engineering which deals with water at rest or in motion. It deals mainly with the practical problems of flow of water and is based upon the results obtained from experiments. It provides various principles to solve practical problems in water supply, irrigation engineering, water power and hydraulic machines.

Pneumatics is that branch of engineering which deals with the action of compressed air or any other gas in operating various machines and equipment's.

FLUID Fluid may be defined as a substance which is capable of flowing and offers practically no resistance to the change of shape**.**

A fluid has no definite shape of its own, but takes the shape of the containing vessel. A fluid has no tensile strength or very little of it and it can resist compressive forces when it is kept in a container, When subjected to shearing force, a fluid deforms continuously as long—as force is applied. For mechanical analysis, a fluid is considered to be continuum i.e. a continuous distribution of matter with no void or empty space. Some of the examples of fluids are water, oil, air, gases and vapours.

Fluids may be classified as follow:
1. Liquids,
2. Gases including vapours.

1. **Liquids**: Liquids occupy a definite volume and are not affected appreciably by change in temperature or compression. Water, oil, honey, glycerine, paint, blood etc. are the examples of liquids.

2**. Gases including vapours**: Gases and vapours do not occupy a definite volume, but take the shape and volume of vessels containing them. Gases and vapours readily respond to change • temperature. These are capable of being compressed to a considerably small volume under high pressure.

TYPES OF FLUIDS

The fluids may be classified into the following two categories
1. Ideal fluids,
2. Real fluids.

1. Ideal Fluids: the fluids which are incompressible and have no viscosity and surface tension. These are only imaginary fluids and do not exist.
However, air and water may be considered as ideal fluids without much error.

2. Real Fluids: The fluids which possess properties such as viscosity, surface tension and compressibility are called real fluids. The fluids actually available in nature are real fluids. These fluids offer a certain amount of resistance when these are set in motion.

These are further subdivided into the following categories

(i) Newtonian fluids,
(ii) Non-Newtonian fluids,
(iii) Ideal plastic fluids,
(iv) Thixotropic fluids.

(i) **Newtonian Fluids**: The fluids in which shear stress is directly proportional to the rate of shear strain (or velocity gradient) are called Newtonian fluids. These fluids follow Newton's law of viscosity.

(ii) **Non-Newtonian Fluids**: The fluids in which shear stress is not proportional to the rate of shear strain (or velocity gradient) are called non-Newtonian fluids.

(iii) **Ideal Plastic Fluids**: The fluids in which shear stress is more than yield stress value r and shear stress is directly proportional to the rate of shear strain (velocity gradient) are called ideal plastic fluids.

(iv) **Thixotropic Fluids**: The fluids in which shear stress is more than Yield stress value and shear stress is not proportional to the rate of shear strain (or velocity gradient) called thixotropic fluids. e.g. printer's ink.

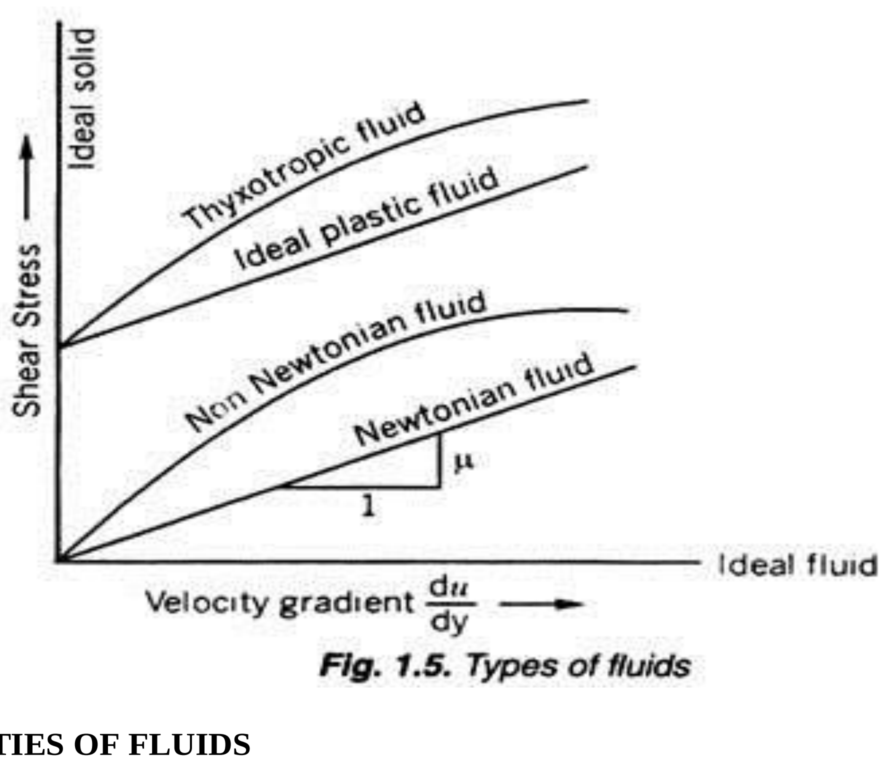


Fig. 1.5. Types of fluids

PROPERTIES OF FLUIDS

Some of the important properties of fluids are as follow

(i) Mass density,
(ii) Specific weight
(iii) Specific volume
(iv) Specific gravity
(v) Viscosity
(vi) Vapour pressure
(vii) Cohesion
(viii) Adhesion
(ix) Surface tension
(x) Capillarity

(xi) Compressibility

Mass Density

Mass density of fluid may be defined as mass of fluid per unit volume. It is generally by p (Rho). Its S.I. unit is kg/m3.

$$\text{Density}, \rho = \frac{\text{Mass}}{\text{Volume}} \; \frac{\text{kg}}{\text{m}^3}$$

The mass density of water is taken as 1000 kg/m3 at 4°C.

Specific Weight

Specific weight of fluid may be defined as weight of fluid per unit volume It is denoted by w. Its SI unit is N/m3. Specific weight varies from place to place due to the change of acceleration due to gravity (g).

Mathematically,

$$\text{Specific weight}, w = \frac{\text{Weight}}{\text{Volume}} \; \frac{\text{N}}{\text{m}^3}$$

Specific weight depends upon mass density and gravitational acceleration. Since gravitational acceleration varies from place to place, therefore, specific weight also varies from place to place. Specific weight also decreases with the increase in temperature. It increases with increase in pressure. However, the specific weight of water is taken as 9810 N/m3 at 4°C.

Specific Volume

Specific volume may be defined as the volume occupied by fluid per unit mass.it is generally denoted by v. its SI unit is m ^3/kg.

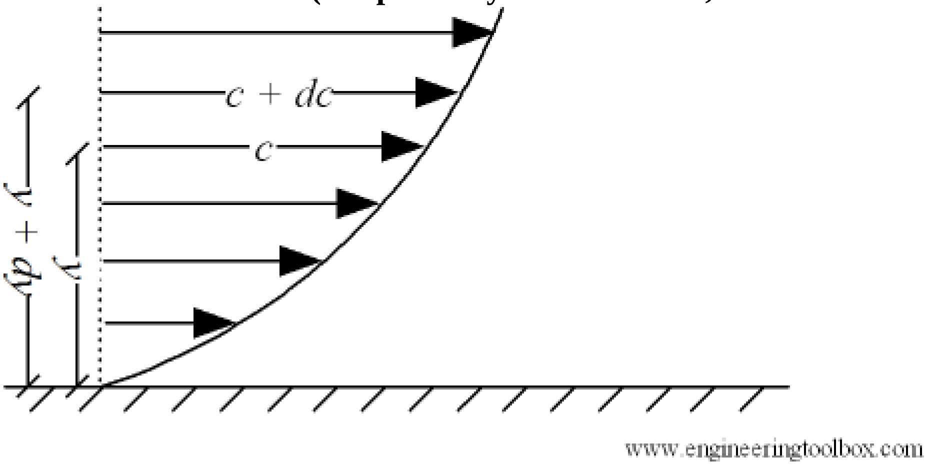
Specific volume is reciprocal of mass density.

Specific gravity,

Specific gravity is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material. Specific gravity for liquids is nearly always measured with respect to water at its densest (at 4 °C or 39.2 °F); for gases, air at room temperature (20 °C or 68 °F) is the reference. The term "relative density" is often preferred in scientific usage. It is defined as a ratio of density of particular substance with that of water.

Viscosity

Viscosity is a measure of a fluid's resistance to flow. It describes the internal friction of a moving fluid. A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction.



A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion.
Gases also have viscosity, although it is a little harder to notice it in ordinary circumstances.

Kinematic viscosity
The ratio of viscosity to mass density of Fluid is called kinematic viscosity.
SI unit m^2/s. Another unit of KV is Stroke.
1 m^2/s=10000 strokes

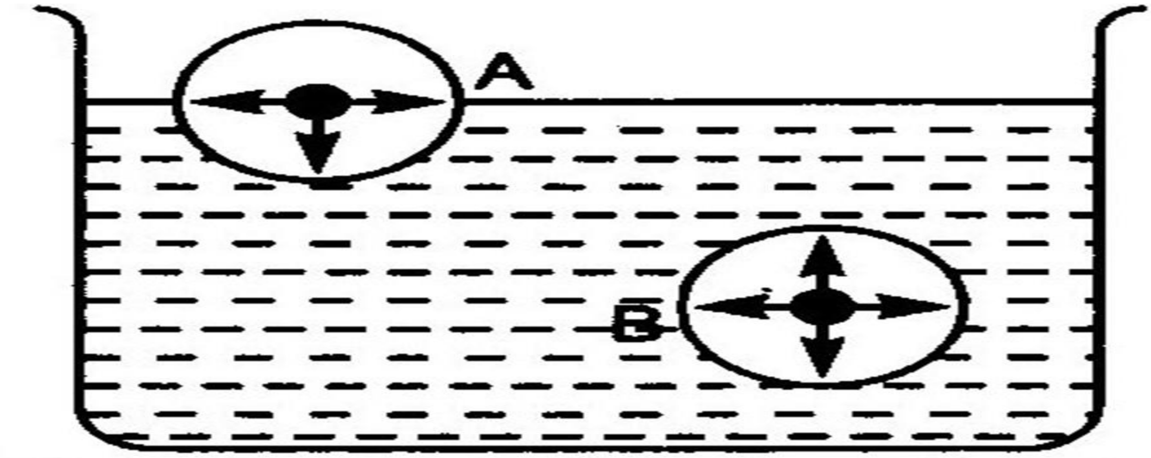
Compressibility
Compressibility of a fluid may be defined the property by virtue of which the fluid undergoes a change in volume under the action of external pressure. All the fluids can be compressed by the application of external pressure and when the pressure is removed, the compressed volumes of fluids expand to their on volumes, Thus fluids also possess elastic characteristics just like elastic solids.
The variation in the volume of water with the variation of pressure is so small that for practical purposes, it is neglected. Thus water is considered as incompressible fluid, Compressibility of fluid may be expressed as the reciprocal of bulk modulus of elasticity (K).
Bulk modulus of elasticity (K) may be defined as the ratio of compressive stress to volumetric strain.

Cohesion
Cohesion is the property of liquid by virtue of which it can withstand tension, property of liquid is due to the intermolecular attraction between the molecules of the liquid. The property of surface tension is also due to cohesion. The droplet of water hanging down the tap keeps its entity together due to the property of cohesion

Adhesion
Adhesion is the property of liquid by virtue of which it adheres (stick.) to the solid body with which it is in contact. Whereas cohesion is due to its inter-molecular attraction between the molecules of the liquid, adhesion is due to the forces of attraction between the molecules of the liquid and the molecules of the solid body, A droplet of water before falling from the tip of the finger exhibits the property of adhesion,

Surface Tension
The property of liquid by virtue of which the free surface of the liquid acts as a

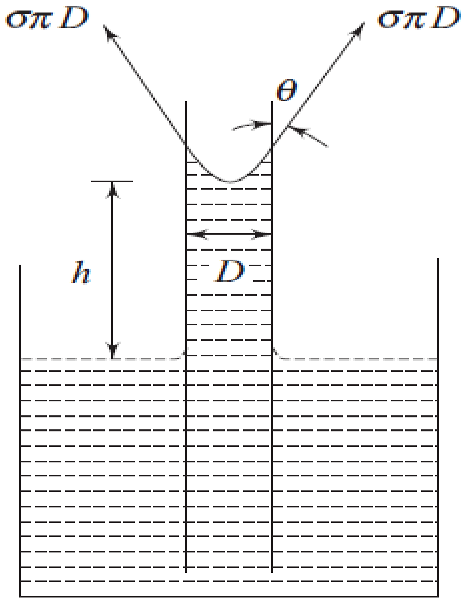
stretched elastic membrane capable of bearing a slight amount of tension is called surface tension.



Mathematically, the surface tension may be defined as the force required unit length of Film in equilibrium. Its S.I unit is N/m
The property of surface tension can be described by slowly placing a steel needle on the surface of water in the horizontal position. The needle will continue floating on the surface of water exhibiting a little depression on the surface: The property of surface tension is due to the cohesion between the particles of the liquid.

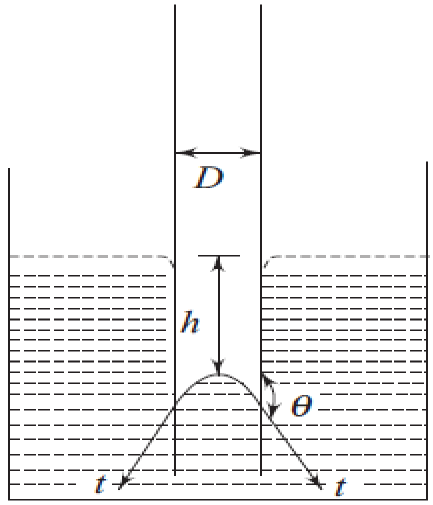
Capillarity

Capillarity is the phenomenon by which a liquid rises up or falls down in a thin glass tube in comparison to the general liquid level in the vessel, when the glass tube is dipped into the mass of liquid. The rise of liquid is known as capillary rise whereas the fail of liquid Is known as capillary depression. It is generally expressed in terms of mm or cm of liquid. The phenomenon of capillarity is due to the effect of cohesion and adhesion of liquid particles, (If the cohesion between the liquid particles is less than the liquid in the tube will rise to the general more than adhesion, then the liquid in the tube will go down the liquid. the adhesion with the glass tube, then level of the liquid, If the cohesion;



Capillary rise

Adhesion > cohesion
liquid wets the surface



Capillary depression

Adhesion < cohesion
liquid stays away from
the surface

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT
E-NOTES , Subject : Hydraulic and Pneumatic, Subject Code: 181741 ,
Course: Diploma , Branch : Mechanical Engineering , Sem.-4th , Chapter Name: Pressure and its measurements
(Prepared By: Ms. Promila , Assistant Professor , MED)

VERY SHORT ANSWER QUESTIONS

Q.1 Define pressure of a liquid.
Ans When a liquid is contained in a vessel, it exerts force on the sides and bottom of vessel due to its weight. This force is known as pressure of the liquid. The direction of pressure is always at right angle to the surface.

Q.2. Write the S.I. unit of pressure of liquid.
Ans. Newton. (N)

Q•3 Define intensity of pressure of a liquid.
Ans. The pressure exerted •by the liquid per unit area is called intensity of pressure. Intensity of pressure is also known as unit pressure or specific pressure. Let P is the pressure acting on a surface of area A, then intensity of pressure p will be
p= P / A

Q.4. Write the Si unit of intensity of pressure of a liquid.
Ans. N/m2.

Q.5 Define pressure head of a liquid.
Ans. When pressure is expressed in terms of height of liquid, it is commonly called pressure head.

Q.6. Write the expression for pressure head of a liquid.
Ans. Pressure head, h = p/w

Q.7.State Pascal’s law.
Ans. This law states that the liquid id at rest transmit pressure with equal intensity in all directions and the direction of liquid pressure is always perpendicular to the surface on which it acts.

Q.8, Write some applications of Pascal’s law.
Ans. Hydraulic press, hydraulic jack, hydraulic crane, hydraulic lift hydraulic intensifier etc

Q.9 Define atmospheric pressure.
Ans. Atmospheric pressure at any place is due to the weight of air column above that place.

Q.10 which instrument is used to measure atmospheric pressure?
Ans. Barometer.

Q11. What is the value of atmospheric pressure at mean sea level?
Ans. The value of atmospheric pressure is taken as 1.01325 x 105 N/m2 or 1.01325 bar at mean sea level. It can also be expressed as 76 cm of mercury or 10.34 m of water.

Q.12 Give the relationship between absolute pressure, atmospheric pressure and gauge pressure.
Ans. Absolute pressure = Atmospheric pressure + Gauge pressure

Q.13 Give the relationship between absolute pressure, atmospheric pressure and vacuum pressure.
Ans. Absolute pressure = Atmospheric pressure — Vacuum pressure

Q.14. Name the devices used to measure the pressure of liquids.
Ans. The pressure of liquid may be measured with the help of following devices:

1. Manometers, 2. Mechanical gauges.

Q.15 Define manometers
Ans. Manometers are the devices which are used to measure pressure at a point in a liquid by balancing the column of the liquid by the same or another column of liquid.

Q.16. Name types of manometers.
Ans. 1. Simple manometers
2. Differential manometers.

Q.17 Define mechanical gauges.
Ans. Mechanical gauges are the devices which are used to measure the pressure by balancing the liquid column by the spring or dead weight.

Q.18 Classify mechanical gauges.
Ans.
1. Bourdon's tube pressure gauge,
2. Dead weight pressure gauge,
3. Diaphragm pressure gauge,
4. Bellow's pressure gauge.

Q19 write Name of important types of simple manometers.
Ans.
1. Piezometer
2. U-tube manometer,
3. Single column manometer.

Q.20. Write the function of piezometer.
Ans. A piezometer is a simplest form of Manometer which is used to measure gauge pressure

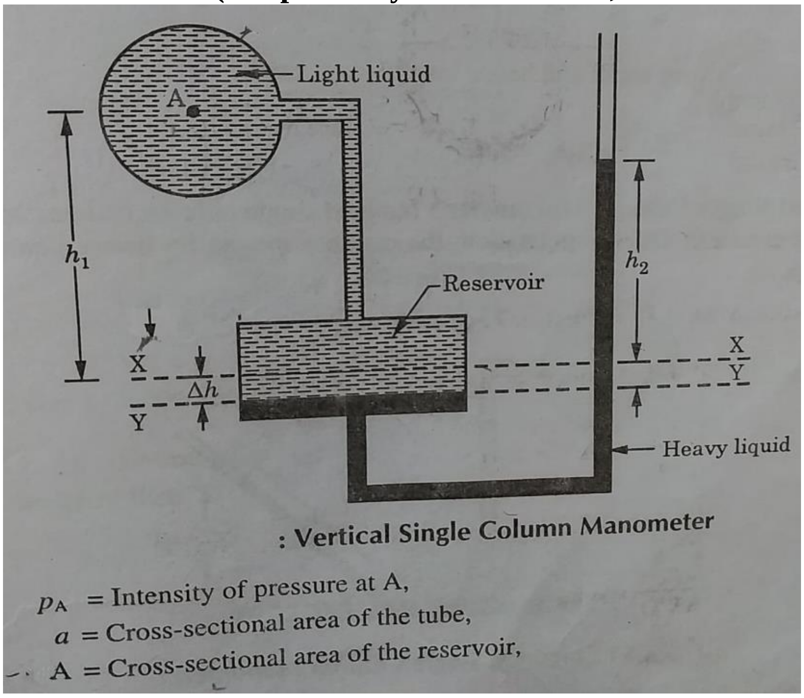
Q•21. Name two types of single column manometers.
Ans.
1. Vertical single column manometer,
2. Inclined single column manometer.

Q•22. What are differential manometers?
Ans. Differential manometers are used to measure the difference of pressures between two Points in the same pipe or in two different pipes. A differential manometer consists of a U-tube Whose both ends are connected to the points whose difference of pressures is to be measured.

Q.23. Name common types of differential manometers.
Ans. 1. U-tube differential manometer,
2. Inverted U-tube differential manometer.

6. Explain, in brief, dead weight pressure gauge.

LONG ANSWER QUESTIONS:
1. Derive an expression for pressure measured by a vertical single column manometer.



Let us consider a vertical single column manometer whose one end is connected to a pipe containing light liquid under pressure. The reservoir contains heavy liquid say mercury. The pressure in the pipe pushes the heavy liquid in the reservoir downwards. This will cause fall of heavy liquid level, of course this is very small. This movement of heavy liquid causes a considerable rise of heavy liquid in the right limb. Let X-X be the datum before Connecting the manometer to the pipe and YY. Be the datum after connection.

Let,

ρ_1 = density of liquid for which pressure has to be determined

ρ_2 = density of manometer liquid (assume mercury)

S_1 = Specific gravity of liquid for which pressure has to be determined

S_2 = Specific gravity of manometer liquid

δh = Fall in the level of liquid in the tank

A = Area of cross-section of the tank

a = Area of cross-section of the right limb

h = Pressure head of fluid in the pipe (as head of water)

Let h be the pressure in terms of height of fluid in the pipe.

h_1 is the distance from the datum line XX to the centre of pipe

h_2 is the height of heavy liquid from the datum line XX in the right limb

The rise in the manometer fluid in the right limb will be equal to the fall of level in the tank.

Therefore:

$\Delta h\ A = a.h_2$

Pressure in the right limb at YY= $(h_2 + \delta h)S_2$

According to Pascals law,

Leftlimb right limb

$$h+(h_1+\delta h)S_1=(h_2+\delta h)S_2$$

$$h+h_1S_1+\delta h.S_1=h_2S_2+\delta h.S_2$$

$$h=\delta h(S_2-S_1)+(h_2S_2-h_1S_1)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

From equation (i) and (ii)

$$h=\frac{ah_2}{A}(S_2-S_1)+(h_2S_2-h_1S_1)$$

If the cross sectional area of the tank A is very large compared to cross sectional area of the right limb then i.e. A >> a, then,

Ratio of a/A will be zero and the above equation can be re-written as:

$$h=(h_2S_2-h_1S_1)$$

2. **Derive an expression for pressure difference measured by a U-tube differential manometer**

Let,

ρ_1 = density of liquid flowing in the pipeline

ρ_2 = density of manometer liquid (assume mercury)

S = Specific gravity of liquid for which pressure has to be determined

S_1 = Specific gravity of manometer liquid

h_A be the pressure in terms of height of fluid in the pipe at point A

h_B be the pressure in terms of height of fluid in the pipe at point B

h is the distance of mercury level in the right limb from the datum line

h_1 is the height of manometer liquid level in the right limb from the centre of pipe at point B.

Pressure difference at two points in a pipe.

Left limb eq. $h_A+(h+h_1)S\ldots\ldots\ldots\ldots\ldots(i)$

Right limb eq. $h_B+h_1S+hS_1\ldots\ldots\ldots\ldots\ldots(ii)$

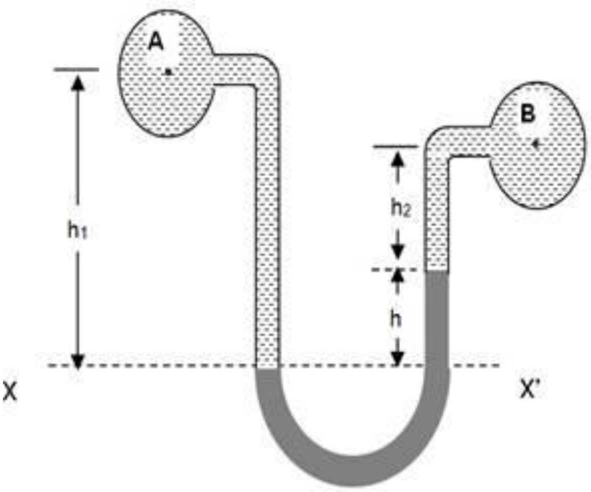
* Pressure is same at the datum line :

$$h_A+(h_1+h)S=h_B+h_1+hS_1$$

$$h_A-h_B=-h_1S-hS+-h_1S+hS_1$$

$$h_A-h_B=h(S_1-S)$$

U-tube upright differential manometer connected between two pipes at different levels and carrying different fluids



3.

Vertical differential manometer (pressure difference between two pipes)

Left limb eq : $h_A - h_1S_1$..........................(i)

Right limb eq : $h_B - h_2S_2 - hS$..............(ii)

* Pressure is same at the datum line :

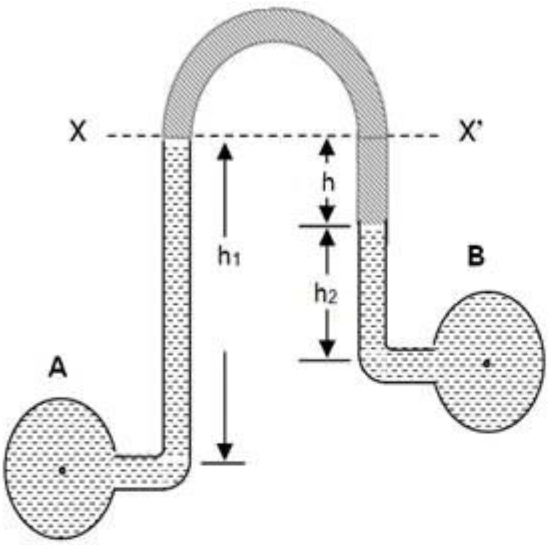
$$h_A + h_1S_1 = h_B - h_2S_2 - hS$$

$$h_A - h_B = h_1S_1 - h_2S_2 - hS$$

3. Derive an expression for pressure difference measured .by inverted U-tube manometer

U-tube Inverted Differential Manometer

In such types of manometers light fluids for e.g. oil is used as manometer fluid.



Inverted differential manometer

Let,

S_1 = Specific gravity of liquid in pipe A

S_2 = Specific gravity of liquid in pipe B

S = Specific gravity of manometer liquid

h_A be the pressure head in terms of height of fluid in the pipe at point A

1. h_B be the pressure head in terms of height of fluid in the pipe at point B

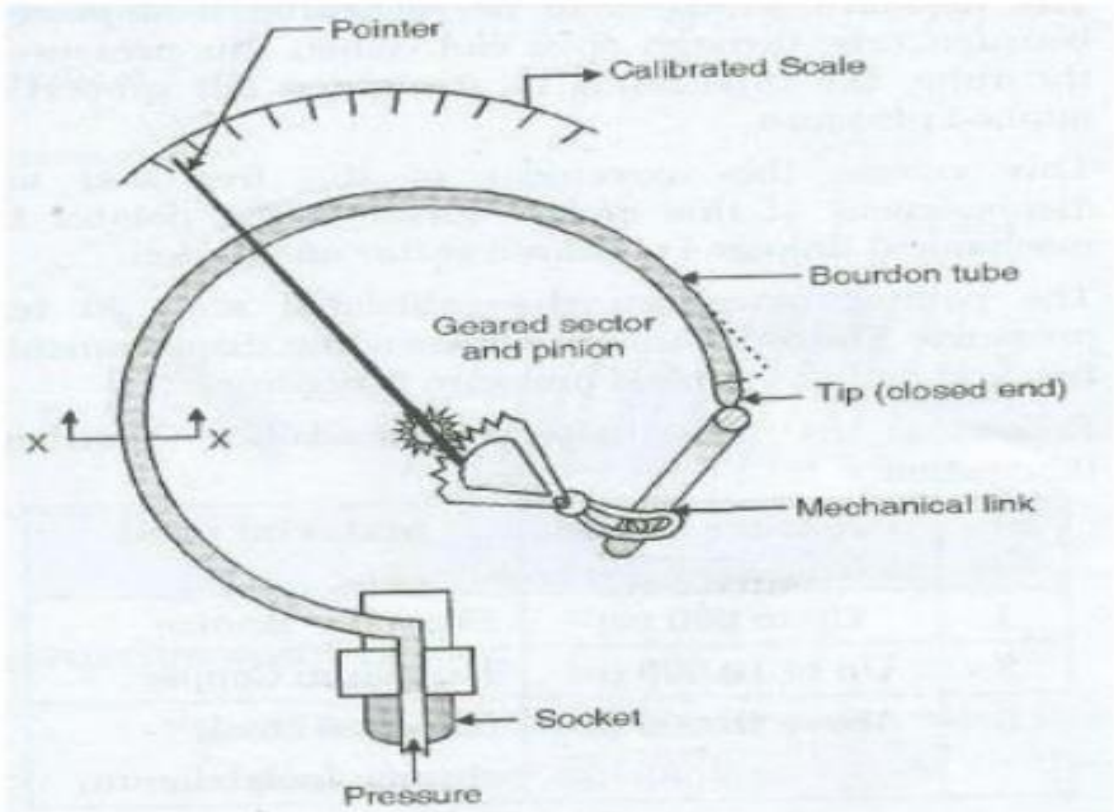
h is the distance of manometer liquid level in the right limb from the datum line XX

h_1 is the height of manometer liquid level in the left limb from the from the datum line XX

h_2 is the height of manometer liquid level in the right limb from the from the centre of pipe at point B

$$\text{Left limb eq}: h_A + h_1 S_1$$
$$\text{Right limb eq}: h_B + h_2 S_2 + hS$$
$$\text{*Pressure is same at the datum line :}$$
$$h_A + h_1 S_1 = h_B + h_2 S_2 + hS$$
$$h_A - h_B = h_2 S_2 - h_1 S_1 + hS$$

4. Explain Bourdon's tube pressure gauge With the help of neat sketch.



Ans. Bourbon tube pressure gauge can measure gauge as well as vacuum pressure. It consists of elliptical tube XYZ bent into an arc of a circle. this bent up tube is called Bourdon's tube.
When one end of this tube is attached to e fluid pipe (whose pressure is to be found out), the internal stress causes the tube to expand. The tube tries to straighten itself. Since the tube is encased in a circular Cover, it, therefore, tends to become circular instead of straight. The other end which is attached with a simple pinion and sector arrangement causes the movement of the pointer which is attached to the arrangement, there by, showing the reading on the dial gauge. This gauge is used for measuring high as well as low pressures.

If Bourdon's tube is made of phosphor bronze, then it is used for measuring low pressures and if the Bourdon's tube is made of nickel steel, then it is used for measuring high pressures.

5. Write the advantages and limitations of manometers.

Following are the benefits or advantages of Manometer:
It is simple in construction.
It has higher accuracy.
It can be used to measure pressure, temperature, flow and other process variables.

Following are the disadvantages of Manometer:
Manometers have poor dynamic response.
They are fragile and hence offer less portability.
They have smaller operating range which is on the order of 1000 KN/m^2.
The monomeric fluids density depends on temperature. Hence errors may result due to
Change in the temperature.

CHAPTER 3

FLOW of Fluids

INTRODUCTION

When the liquids are in rest position, their behavior can be predicted easily by the application of certain laws of hydrostatics. This is due to the fact that these laws rigidly conform to the results obtained practically.

However, when the liquids are moving, then these are subjected to varied conditions. As such, the theoretical results have to be supplemented with the practical findings in order to reach an agreeable solution. In this chapter, we shall study the liquid flow and forces causing the same.

TYPES OF FLOW

The flow of liquid is quantitatively represented by its velocity at a certain point. Because the liquids do not flow as a combined unit like solids, therefore, the velocity of liquids is different at different points of flow. Due to the variation of velocity, the liquids may have following types of flows:

1. Steady and unsteady flow,
2. Uniform and non-uniform flow,
3. Laminar and turbulent flow.

Study and Unsteady Flow

Steady flow may be defined as the type of flow in which liquid characteristics like velocity, pressure, density etc. at a point do not change with time. The flow through a pipe line under Constant head will be a steady flow as the velocity of liquid remains constant at all the time.

On the other hand, unsteady flow is a type of flow in which the liquid characteristics like velocity, pressure, density etc. at point changes with time. The flow through a pipe line under falling head will be unsteady flow as the velocity of liquid decreases with the time.

Uniform and Non-uniform Flow

Uniform flow may be defined as the type of in which the velocity flow at a given instant of time does not change from one point to other.

On the other hand, non-uniform flow is a type of flow in which the velocity of flow at a given instant of time changes from one point to other.

The term uniform or non-uniform flow is generally used for flows in open channels. In case of open Channel, to keep the flow uniform, the frictional head loss in a particular length is compensated by the longitudinal slope of the bed of the channel and due to this, there is no variation in the velocity of flow.

Laminar and Turbulent Flow

Laminar flow may in- defined as the types of flow in which the liquid particles move in layers in such a way that one laver shares over the other layer without causing any interference to each other.

Laminar flow is also known as stream fine flow or viscous flow. For this type of flow, There must be the following conditions

1. Low velocity of flow.
2. High viscosity of liquid.
3. Comparatively small size of conduit pipe in which flow occurs.

Due to the above conditions, the laminar flow is not of common occurrence in hydraulic Engineering.

On the other hand, turbulent flow is a type of flow in which the particles of liquid ore disturbed and they continue mixing with each other forming eddies' (cross currents). In this type of flow, the velocities of various particles of the liquid vary in magnitude and direction from point to point and instant to instant.

RATE OF FLOW OR DISCHARGE

The volume of liquid flowing across any section of pipe or channel per unit time is called rate of flow or discharge. It is generally denoted by Q and its S.I. unit is m3/s. average velocity v.

Then,

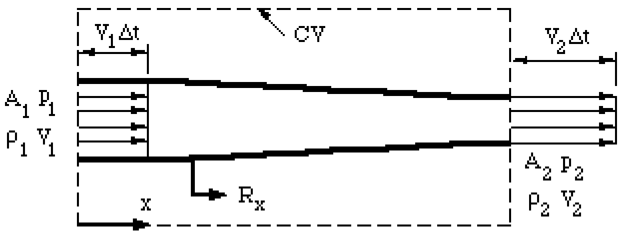
Let us consider a pipe of cross-sectional area A in which a liquid is flowing full with an Discharge,

$Q = Av$

CONTINUITY EQUATION

This equation is based on the principle of conservation of mass. It added or removed from the pipe at any length, then the mass of liquid transverse sections of the pipe will be same.

Let us consider a taper pipe running full with liquid as shown in fig



$$\textit{volume flow in over } A_1 = A_1 V_1 \Delta t$$
$$\textit{volume flow out over } A_2 = A_2 V_2 \Delta t$$

Therefore

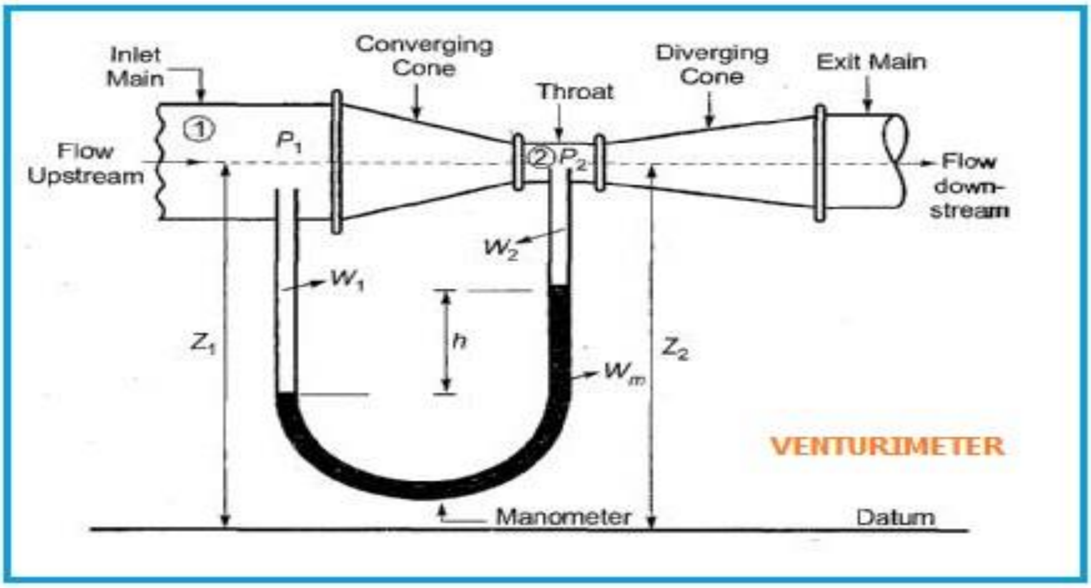
$$\textit{mass in over } A = \rho A_1 V_1 \Delta t$$
$$\textit{mass out over } A = \rho A_2 V_2 \Delta t$$

$$\textit{So:} \quad \boxed{\rho A_1 V_1 = \rho A_2 V_2}$$

VENTURI METER

The venturimeter has a converging conical inlet, a cylindrical throat and a diverging recovery . It has no projections into the fluid, no sharp corners and no sudden changes in contour.

The converging inlet section decreases the area of the fluid stream, causing the velocity to increase and the pressure to decrease. At the centre of the cylindrical throat, the pressure will be at its lowest value, where neither the pressure nor the velocity will be changing. As the fluid enters the diverging section, the pressure is largely recovered lowering the velocity of the fluid. The major disadvantages of this type of flow detection are the high initial costs for installation and difficulty in installation and inspection. The Venturi effect is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The fluid velocity must increase through the constriction to satisfy the equation of continuity, while its pressure must decrease due to conservation of energy: the gain in kinetic energy is balanced by a drop in pressure or a pressure gradient force. An equation for the drop in pressure due to Venturi effect may be derived from a combination of Bernoulli’s principle and the equation of continuity.

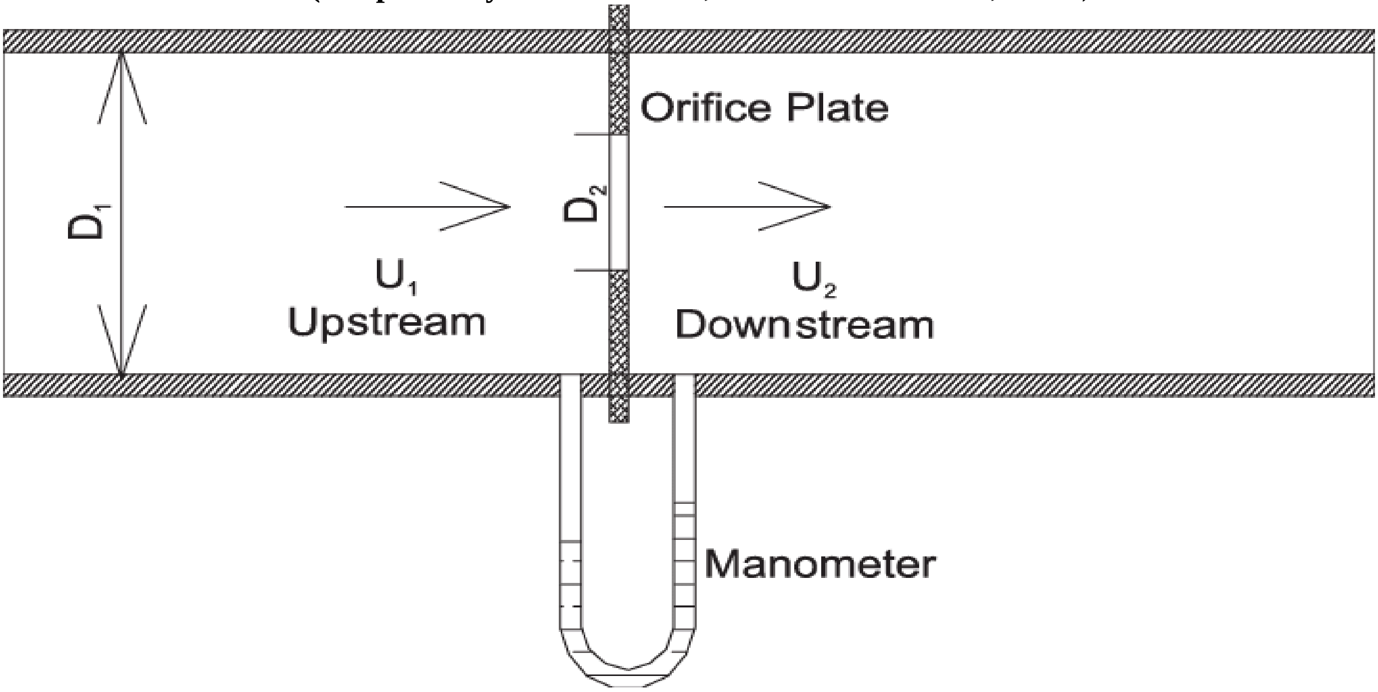


ACTUAL DISCHARGE:
Q act = A x h / t (m3 / s)
THEORTICAL DISCHARGE:
Qth = a 1 x a 2 x √ 2 g h / √ a 1 2 – a 2 2 (m3 / s)
Where:
A = Area of collecting tank in m2
h = Height of collected water in tank
a 1 = Area of inlet pipe in m2
a 2 = Area of the throat in m2
g = Specify gravity in m / s2
t = Time taken for h cm rise of water
H = Orifice head in terms of flowing liquid = (H1 ~ H2) (s m /s 1 - 1)
Where: H1 = Manometric head in first limb
H2 = Manometric head in second limb s m = Specific gravity of Manometric liquid
(i.e.) Liquid mercury Hg = 13.6
s1 = Specific gravity of flowing liquid water = 1

ORIFICE METER

Orifice meter is a device used for measuring the rate of flow of a fluid flowing through a pipe. It consists of flat circular plate which has a circular hole, in concentric with the pipe. This is called orifice.

An orifice meter is essentially a cylindrical tube that contains a plate with a thin hole in the middle of it. The thin hole essentially forces the fluid to flow faster through the hole in order to maintain flow rate. The point of maximum convergence (vena contracta) usually occurs slightly downstream from the actual physical orifice. This is the reason why orifice meters are less accurate than venturi meters, as we cannot use the exact location and diameter of the point of maximum convergence in calculations. Beyond the vena contracta point, the fluid expands again and velocity decreases as pressure increases.



ACTUAL DISCHARGE:
Q act = A x h / t (m3 / s)
THEORTICAL DISCHARGE:
Q th = a 1 x a 2 x √ 2 g h / √ a 1 2 – a 2 2 (m3 / s)
Where: A = Area of collecting tank in m2
h = Height of collected water in tank
a 1 = Area of inlet pipe in, m2
a 2 = Area of the throat in m2
g = Specify gravity in m / s2
t = Time taken for h cm rise of water
H = Orifice head in terms of flowing liquid = (H1 ~ H2) (s m / s 1 - 1)
Where: H1 = Manometric head in first limb
H2 = Manometric head in second limb
s m = Specific gravity of Manometric liquid (i.e.) Liquid mercury Hg = 13.6
s1 = Specific gravity of flowing liquid water = 1

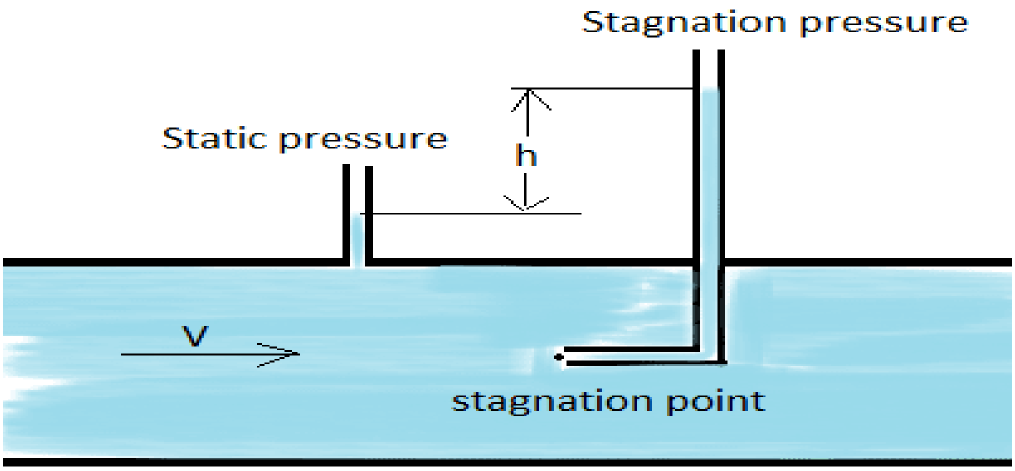
PITOT TUBE

The pitot tube installed in the flow stream measures the direct pressure at the contact pitot tube hole and a second measurement is required, being of static pressure. The difference between the two measurements gives a value for dynamic pressure.

The pitot meter consists of a tube pointing directly toward the flow. The fluid enters through the impact hole and there can one or two other holes in the pitot tube, which are the static pressure source.

For a simple pitot tube we should arrange one another pressure sensing element to measure the static pressure. The axis of tube measuring the static pressure should be perpendicular to the boundary and free from burrs so that the boundary is smooth.

A pitot tube is a simple round cylinder with one end opened with a small hole and other end enclosed. The fluid flowing through the pipeline enters the pitot tube and rest there. There is another chamber within the pitot tube filled with fluid with static pressure. A diaphragm separates both the chambers.



The difference in level between the liquid in the tube and the free surface becomes the measure of dynamic pressure. The flow rate, like other devices, is calculated from the square root of the pressure.

In calculating the flow rate from the pressure, the calculation is dependent on such factors as tube design and the location of the static tap. The Pitot-static probe incorporates the static holes in the tube system to eliminate this parameter.

Measuring the static pressure and the impact pressure are connected to the proper differential pressure meter for the determination of flow velocity and thus the flow rate.

Advantages:

1. Small and do not contain any moving parts
2. Low cost
3. Low permanent pressure loss.
4. Ease of installation into an existing system.

Disadvantages:

1. Foreign material in a fluid can easily clog pitot tube and disrupt normal reading as a result.
2. Low accuracy

Low rangeability

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(Prepared By: Ms. Promila , Assistant Professor , MED)

CHAPTER 5
Hydraulic Machines

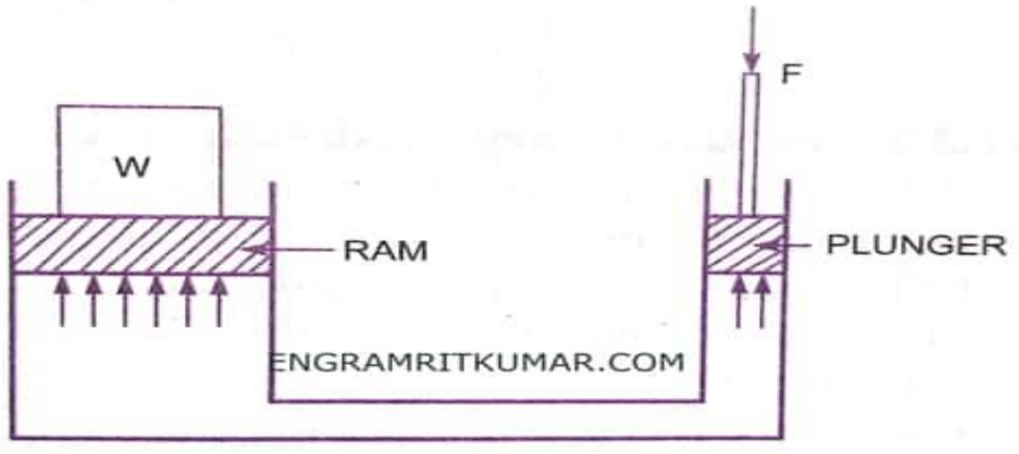
Introduction

“Energy can neither be created nor be destroyed, but it can be transformed from one from to another." This energy can also be stored in a device or equipment, so that they can be used in another form. For example, we know about the function of flywheel in a rotary machine. It gains energy from the prime mover, stores the gained energy, and, when required, releases the energy back into the same system. Thus energy is stored in some form and given back to the system in another form. The point I try to emphasize here is “energy is stored. Hydraulic devices are most widely used energy storage devices, and transfer devices.

HYDRAULIC PRESS

The hydraulic press is practical application of **Pascal’s Law,** which was established by French Mathematician Blaise Pascal in 1647-1648, which is used to lift very heavy weight by the application of much small force.
Pascal’s Law is a principle in fluid mechanics stating that the pressure at a point has infinite direction, and thus the pressure changed at any point in a confined incompressible liquid is transmitted throughout the fluid, such that the same change occurs everywhere.

Working off a Hydraulic Press



The hydraulic press.

The components of a hydraulic press include **cylinders**, **pistons**, and **hydraulic pipes**. The working of the press is quite simple and primitive. The system comprises two cylinders that are filled with a fluid. The fluid present inside the two cylinders is usually oil. The fluid (the oil) is filled into the smaller cylinder, which is also known as the **slave cylinder**.
A piston is inserted into the slave cylinder and pressure is applied. The pressure applied causes the fluid to move through a pipe and into a larger cylinder. The larger cylinder is known as the **master cylinder**. The pressure exerted on the master cylinder and the piston in the master cylinder pushes the fluid back to the slave cylinder. The force applied on the fluid by the slave cylinder results in a large force, which is experienced by the master cylinder. An industrial hydraulic press comes along with what is known as the **press plates**. With the help of these press plates, the material to be worked on is either punched or crushed into sheets.

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Applications
The most common use of hydraulic pressing is for forging, clinching, molding, blanking, punching, deep drawing, and metal forming operations.

HYDRAULIC JACK

A hydraulic jack is a mechanical arrangement that uses the power of fluids for operation. With a hydraulic jack, one can easily lift heavy loads using a small applied force. Normally, this lifting device uses a hydraulic cylinder for applying initial power. Hydraulic jacks have a wide range of applications in railways, defence, earthmoving equipments, aeronautical, material handling equipment, hydropower plants, mining and lifting platforms. The even and stable transmission movement under varying or maximum load made hydraulic jacks suitable for all above applications. Also, jacks using hydraulics can provide more lift over a greater distance.

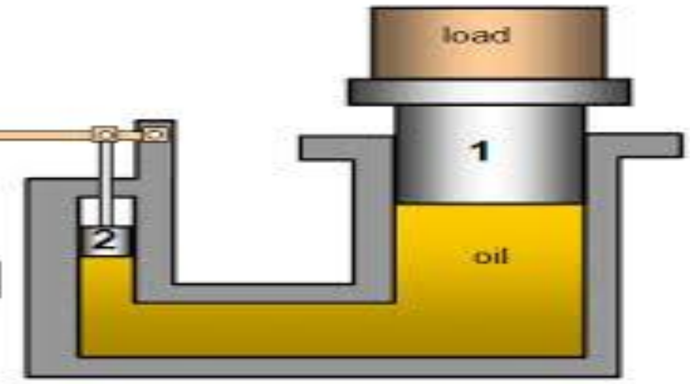

Figure 8

Working

Hydraulic Jack is Works on the Pascal's principle. That is, the pressure applied to a fluid stored in a container will be distributed equally in all directions. The important components of a hydraulic jack are cylinders, pumping system and hydraulic fluid (oil is used commonly). The hydraulic jack design will contain two cylinders (one small and another big) connected to each other using piping. Both cylinders are filled partially using hydraulic fluids. While applying a small pressure on the smaller cylinder, the pressure will be transmitted equally to the larger cylinder through the incompressible fluid. Now, the larger cylinder will experience a force multiplication effect. The force exerted on all points of both cylinders will be the same. But, the force produced by the larger cylinder will be higher and it is directly proportional to the surface area. Other than cylinders, a hydraulic jack will contain a pumping system to push fluid into a cylinder through a one-way valve. This valve will restrict the backflow of hydraulic fluid from the cylinder.

Applications of Hydraulic Jack
Following are some applications of Hydraulic jack.

- Lifting a car or any other vehicle for changing its tires
- To lift heavy loads in industries

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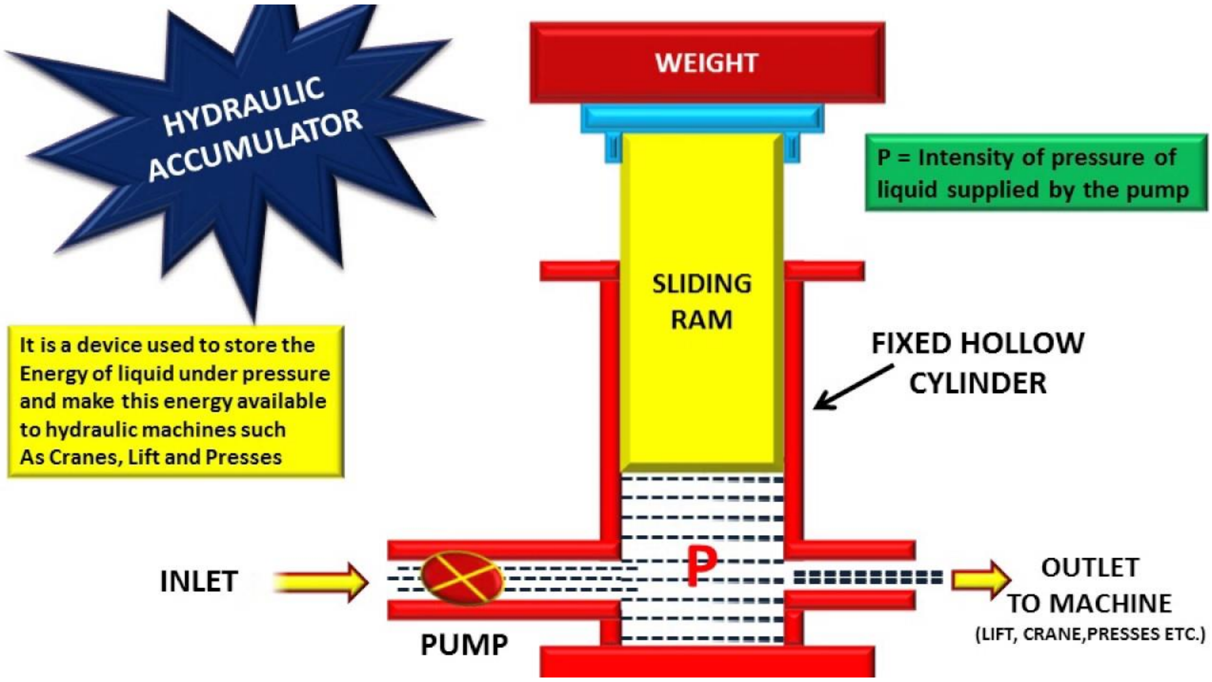
- Cranes are fitted with Hydraulic jacks to lift load
- They are used in lifting platforms
- They are used in material handling equipment
- They are used in earth moving equipment

HYDRAULIC ACCUMULATOR

It is a simple hydraulic device which stores energy in the form of fluid pressure. This stored pressure may be suddenly or intermittently released as per the requirement. In the case of a hydraulic lift or hydraulic crane, a large amount of energy is required when the lift or crane is moving upward. This energy is supplied from the hydraulic accumulator. But when the lift is moving in the downward direction, it does not require a huge amount of energy. During this particular time, the oil or hydraulic fluid pumped from the pump is stored in the accumulator for future use



Working of Hydraulic Accumulator:

An accumulator usually has a cylindrical chamber, which has a piston in it. This piston is either spring loaded or some calculated weight is kept on it or even pneumatically pressurized. The hydraulic pump pumps the fluid into the accumulator, which is nothing but a sealed container. The volume of the container is fixed and cannot be changed. But the quantity of hydraulic fluid being pumped inside the container is increasing continuously. So the pressure of the hydraulic fluid inside the container starts to increase.

The master cylinder, also known as the master brake cylinder, converts the pressure on the brake pedal to hydraulic pressure by feeding brake fluid into the brake circuit and controlling this according to the mechanical force.

Brake lines:

Brake lines are tubes that carry fluid between brake components. Brakes translate the pressure from your foot on the brake pedal into stopping power.

3) Brake pedals in hydraulic brakes:

The brake pedal is the pedal that you press with your foot in order to make a vehicle go slower or stop accordingly with respect to the force applied to the brake pedal.

4) Braking action by Disc/drum (Near wheels):

Different types of brakes (Disc and drum) that slows down the vehicle by the pressure of oil or fluid/ by generating hydraulic pressure directly applied to the wheel brakes.

5) Wheel cylinder in hydraulic braking system:

It is a different cylinder than the master cylinder. It is the cylinder of the wheel. Its function is to exert force onto the shoes so as to bring them into contact with the drum and stop the vehicle with friction

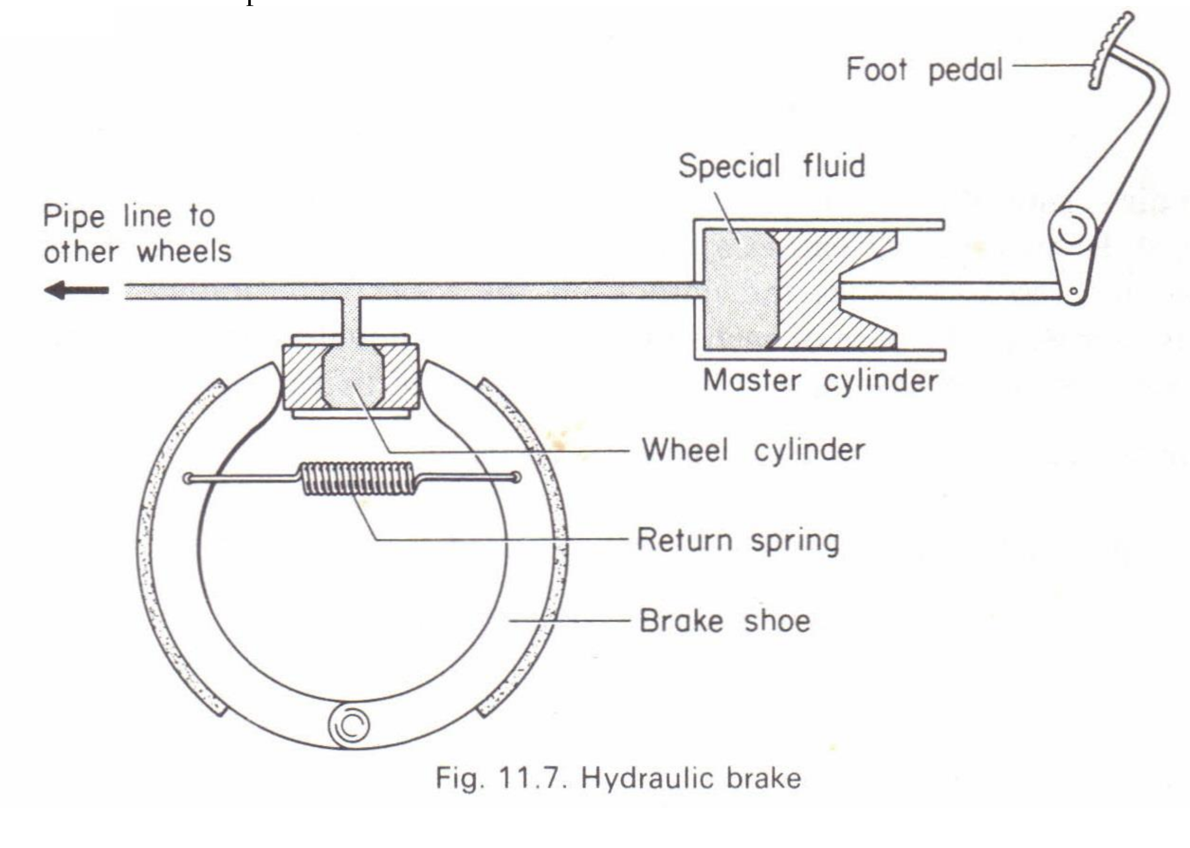
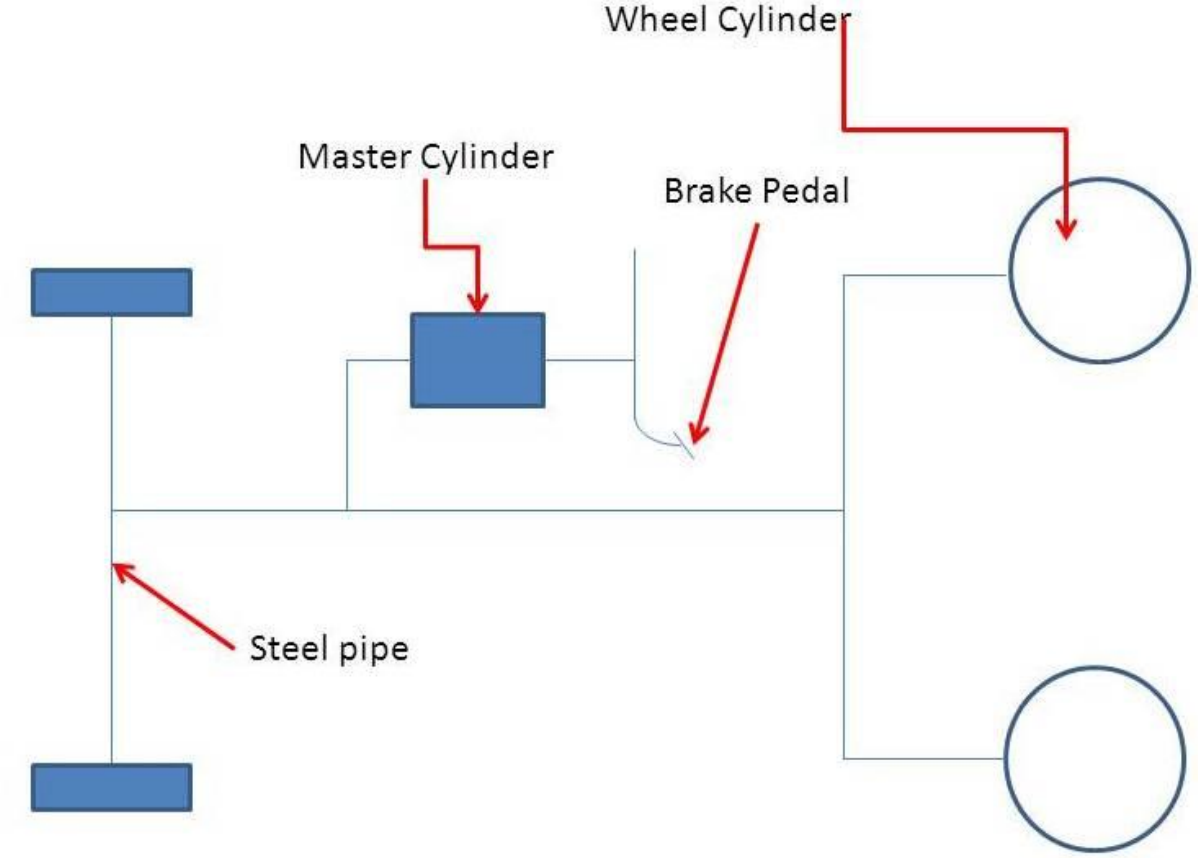


Fig. 11.7. Hydraulic brake



Layout of Hydraulic Braking System

When we release brake pedal, the master cylinder piston returns to its original position due to the return spring pressure. Thus, fluid pressure inside the entire system drops to its original low value, which allows retracting springs on wheel brakes to pull the brake shoes out of contact with the brake drums into their original positions. This causes the wheel cylinder pistons to come back in their original inward position. Thus, the braking mechanism is complete

The brake pedal is connected to the master cylinder piston by means of a piston rod. When we apply brakes or when we press brake pedal, the piston forces into the master cylinder, which increases the pressure of fluid inside the master cylinder and in entire hydraulic system. This pressure is conducted instantaneously to the wheel cylinders on each of the four brakes, where it forces the wheel cylinder pistons outwards. These pistons, in turn, force the brake shoes out against the brake drums. Hence, brakes are applied

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HYDRAULICS RAM

The hydraulic ram is a pump which raises water without any external power for its operation. One essential requirement for the satisfactory operation of a hydraulic ram is the availability of a large quantity of water with a small positive head or height. This large quantity of water at a small height is sufficient to lift small quantity of water to a greater height. It works on the principle of "Water Hammer."

A hydraulic ram is a pump which lifts a small quantity of water to a greater height from a large quantity of water at a smaller height. It works on the principle of water hammer *i.e. when water flowing in a long pipe is brought to rest suddenly by closing the valve or by any other similar cause, there will be a sudden rise in pressure due to destruction of momentum of moving water which raises a small quantity of water to a greater height.*

Construction : A hydraulic ram shown in fig. 5.6 consists of the followings :

1. A supply pipe fitted with an inlet valve which connects the water in supply tank to the valve chamber.
2. A valve chamber fitted with two non-return valves *i.e.* a waste valve and a delivery valve.
3. An air vessel containing compressed air.
4. A delivery pipe connecting the air vessel to the delivery tank.

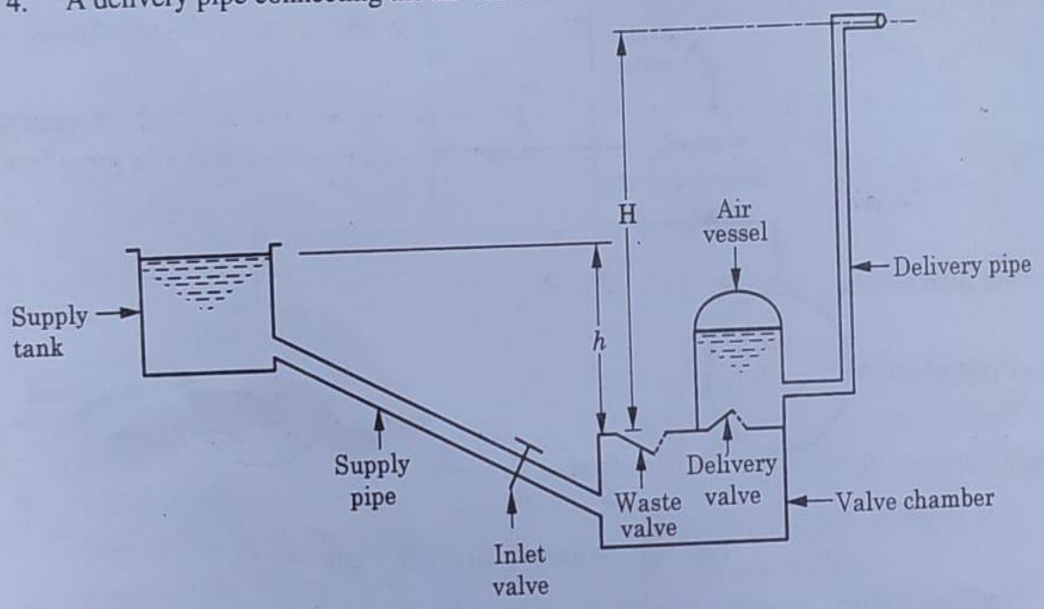

Fig. 5.6 : Hydraulic Ram

Working : When the inlet valve is opened, the water flows from the supply tank to the valve chamber. The level of water rises in the chamber and the waste valve starts moving upward. A stage comes when the waste valve suddenly closes. This sudden closure of waste valve creates high pressure inside the valve chamber. This high pressure forcibly opens the delivery valve and the water enters the air vessel and compresses the air inside the air vessel. This compressed air exerts force on the water in the air vessel and a small quantity of water is raised to a greater height as shown in fig. 5.6. When the water in the chamber loses its momentum, the waste valve opens in the downward direction and water flows from the supply tank to the chamber and the cycle is repeated.

Let
W = Weight of water flowing per second into chamber,
w = Weight of water raised per second,
h = Height of water in supply tank above the chamber,
H = Height of water raised above the chamber.

Energy supplied to the ram by the supply tank

= Weight of water supplied × Height of supply water

$= w \times h$

Energy delivered to the water by the ram

= Weight of water raised ×Height through which water is raised

$= w \times H$

$$\therefore \quad \text{Efficiency of hydraulic ram, } \eta = \frac{\text{Energy delivered by the ram}}{\text{Energy supplied to the ram}}$$

$$= \frac{w \times H}{W \times h}$$

The above expression of efficiency was given by D′ Aubuisson and hence known as D′ Aubuisson's efficiency.

Rankine gave another expression of efficiency. According to Rankine, weight of water (w) is raised through a height (H–h) instead of H, because initially, the water is at a height h from the ram.

$$\therefore \quad \text{Energy supplied} = (W - w) \times h$$

$$\text{Energy delivered} = w \times (H - h)$$

$$\therefore \quad \text{Efficiency, } \eta = \frac{w \times (H - h)}{(W - w) \times h}$$

The above expression of efficiency is called Rankine's efficiency. The above two efficiencies can also be expressed in terms of discharge *i.e.*

$$\text{D}' \text{ Aubuisson's efficiency, } \eta = \frac{q \times H}{Q \times h}$$

$$\text{and Rankine's efficiency, } \eta = \frac{q \times (H - h)}{(Q - q) \times h}$$

where Q = Discharge through supply pipe,
and q = Discharge through delivery pipe.

The system has a chamber with two flap valves and an air vessel. This chamber is connected to the water supply from a supply tank or a water reservoir at a small height. The supply tank and the pumping chamber are separated by a valve which controls the flow of water.

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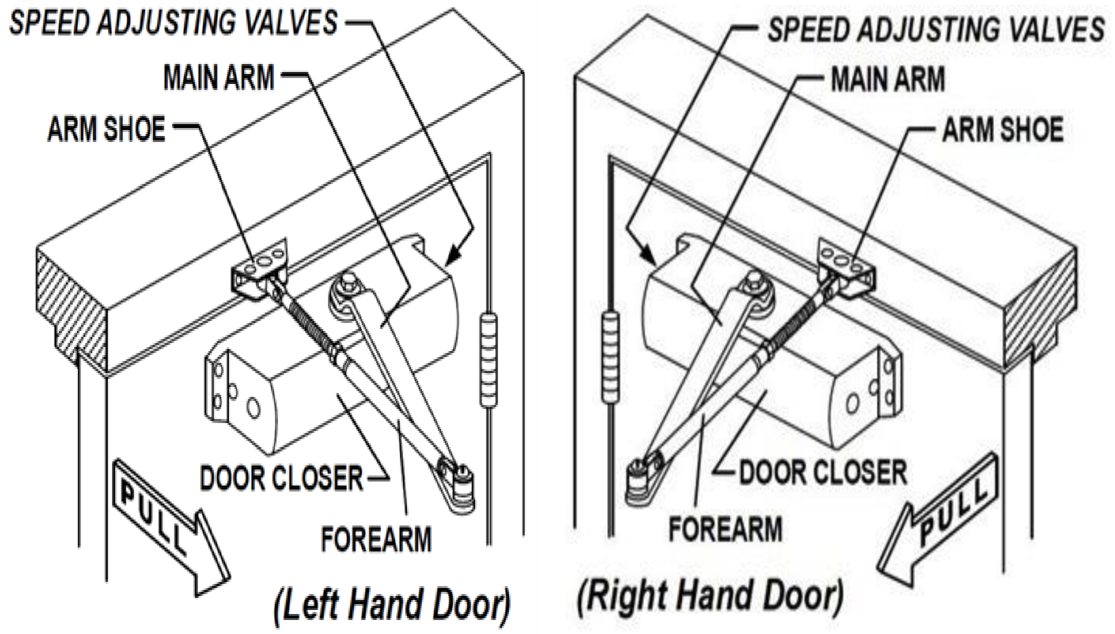
HYDRAULIC DOOR CLOSER

A **hydraulic door closer** is equipment for closing of **doors** by the help of spring control valve such that the phase of closing is slowed down by the **hydraulic** damper.
OR A Hydraulic door closer is a device which closes the door automatically after it is opened or released.
Door closers are used in Hospitals, hotels, Air-conditioned rooms, offices, etc. Door closer fitted at the top of the door leaf.



Construction
It consists of following important parts

1. Body
2. Piston and Plunger
3. Spindle
4. Valves
5. End caps
6. Spring
7. Main arm
8. Adjusting arm
9. Adjusting screw

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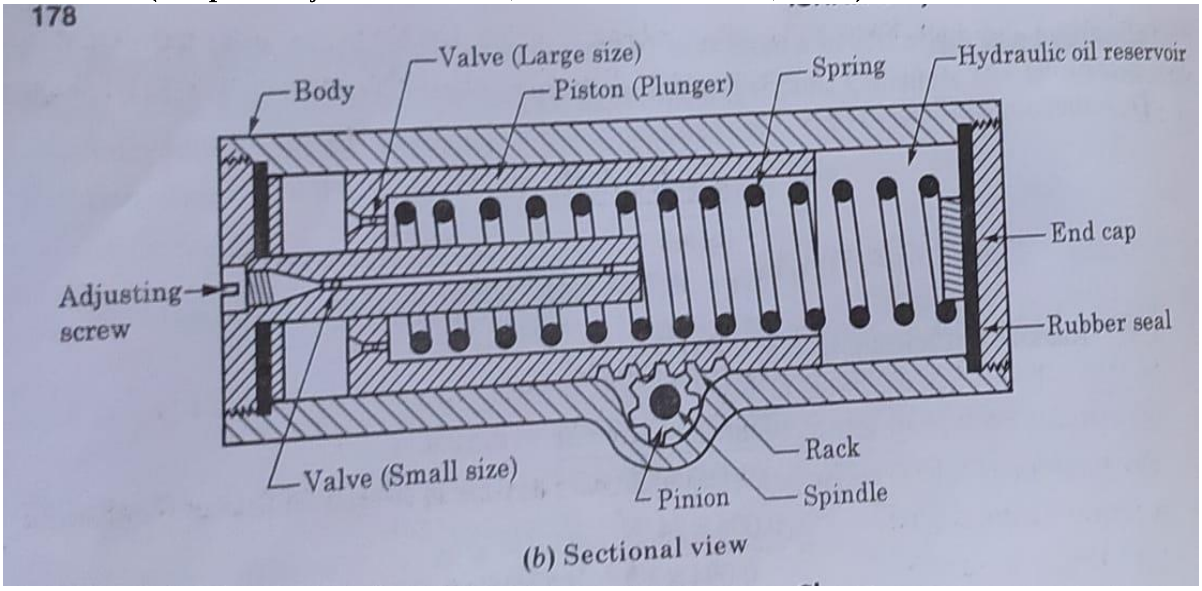


(b) Sectional view

1. Body-The body is made of cast iron and fitted on the door with the help of screw.it is filled with oil
2. Piston or Plunger- Piston or Plunger is hollow rack cut on it. Piston or Plunger moves the bore of the body.
3. Spindle-A pinion is fitted on the spindle. The teeth of pinion meshes with the rack cut on the Piston or Plunger.
4. Valves- There are two large and small size valve
5. End caps- End caps are provided with end seals.
6. Spring- A Spring is fitted between hollow piston and the end seal.
7. Main arm- One end of the main arm is fixed to the spindle and other is fitted with the Adjusting arm with the help of pin joint.
8. Adjusting arm- Adjusting arm should be kept right angle to the main frame as far as possible.
9. Adjusting screw- Adjusting screw is fitted in the end cap. The opening closing of smaller size valve is controlled by Adjusting screw.

WORKING

The hydraulic door closer is simple and easy to work with. One end of the hydraulic door is attached to the door, and the other end is attached to the door frame. When the door is opened, the main arm is swing and rotates the spindle. The spindle then rotates pinion. the rotary motion of pinion is transmitted to the
Piston or Plunger with the help of rack. The plunger moves in right direction and compress the spring and oil .Pressurized oil causes the large size valve to open. The oil flows towards left of Plunger.

Now, when hand force on door is released, the door comes quickly to certain distance due to restoring action of the compressed spring. But oil on the left of plunger stops the motion for a movement. Meanwhile vacuum is created on the right side of the plunger. The small size of valve is opened and oil starts flowing from left to right side of plunger and door starts closing slowly and avoids noise. The slower and faster movement of door is controlled by turning the adjusting screw. End caps with rubber seals control the leakage of oil.

CHAPTER 5
Pumps and Water Turbines

INTRODUCTION

Pump is a hydraulic machine which converts mechanical energy into hydraulic energy whereas turbine hydraulic machine which converts Hydraulic energy into Mechanical energy. In this chapter we will study pumps and there classification, Turbines and its classification.

Pump

It is a hydraulic machine which converts mechanical energy into hydraulic energy. Hydraulic energy means pressure energy so that hydraulic pump converts mechanical energy into pressure energy of the liquid to lift water at lower level to higher level.

Pump can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement and gravity pump.

Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid.

Reciprocating Pump

Reciprocating pump is a positive displacement pump where certain volume of liquid is collected in enclosed volume and is discharged using pressure to the required application. Reciprocating pumps are more suitable for low volumes of flow at high pressures.

Components of Reciprocating Pump

The main components of reciprocating pump are as follows:

1. Suction Pipe
2. Suction Valve
3. Delivery Pipe
4. Delivery Valve
5. Cylinder
6. Piston and Piston Rod
7. Crank and Connecting Rod
8. Strainer
9. Air Vessel

1. Suction Pipe Suction pipe connects the source of liquid to the cylinder of the reciprocating pump. The liquid is suck by this pipe from the source to the cylinder.

2. Suction Valve Suction valve is non-return valve which means only one directional flow is possible in this type of valve. This is placed between suction pipe inlet and cylinder. During suction of liquid it is opened and during discharge it closed.

3. Delivery Pipe Delivery pipe connects cylinder of pump to the outlet source. The liquid is delivered to desired outlet location through this pipe.

4. Delivery Valve Delivery valve also non-return valve placed between cylinder and delivery pipe outlet. It is in closed position during suction and in opened position during discharging of liquid.

5. Cylinder A hollow cylinder made of steel alloy or cast iron. Arrangement of piston and piston rod is inside this cylinder. Suction and release of liquid is takes place in this so, both suction and delivery pipes along with valves are connected to this cylinder.

6. Piston and Piston Rod Piston is a solid type cylinder part which moves backward and forward inside the hollow cylinder to perform suction and deliverance of liquid. Piston rod helps the piston to its linear motion.

7. Crank and Connecting Rod Crank is a solid circular disc which is connected to power source like motor, engine etc. for its rotation. Connecting rod connects the crank to the piston as a result the rotational motion of crank gets converted into linear motion of the piston.

8. Strainer Strainer is provided at the end of suction pipe to prevent the entrance of solids from water source into the cylinder.

9. Air Vessel Air vessels are connected to both suction and delivery pipes to eliminate the frictional head and to give uniform discharge rate.

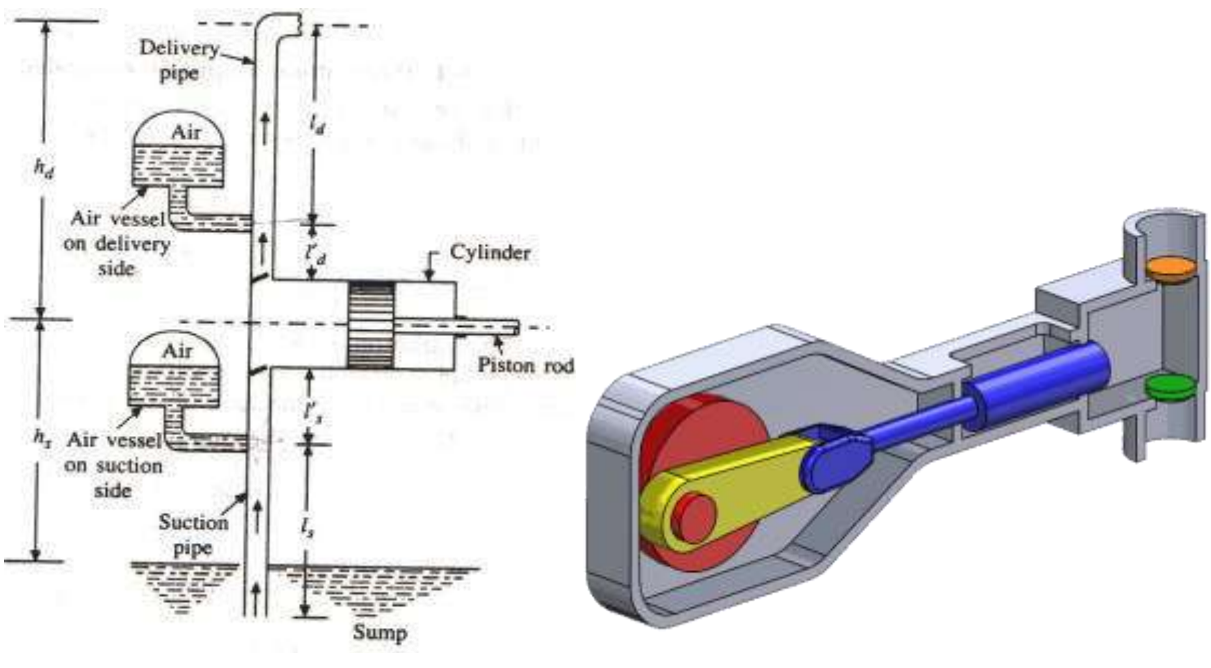


Figure for Reciprocating Pump With Air Vessels

WORKING OF RECIPROCATING PUMP

The working of reciprocating pump is as follows:

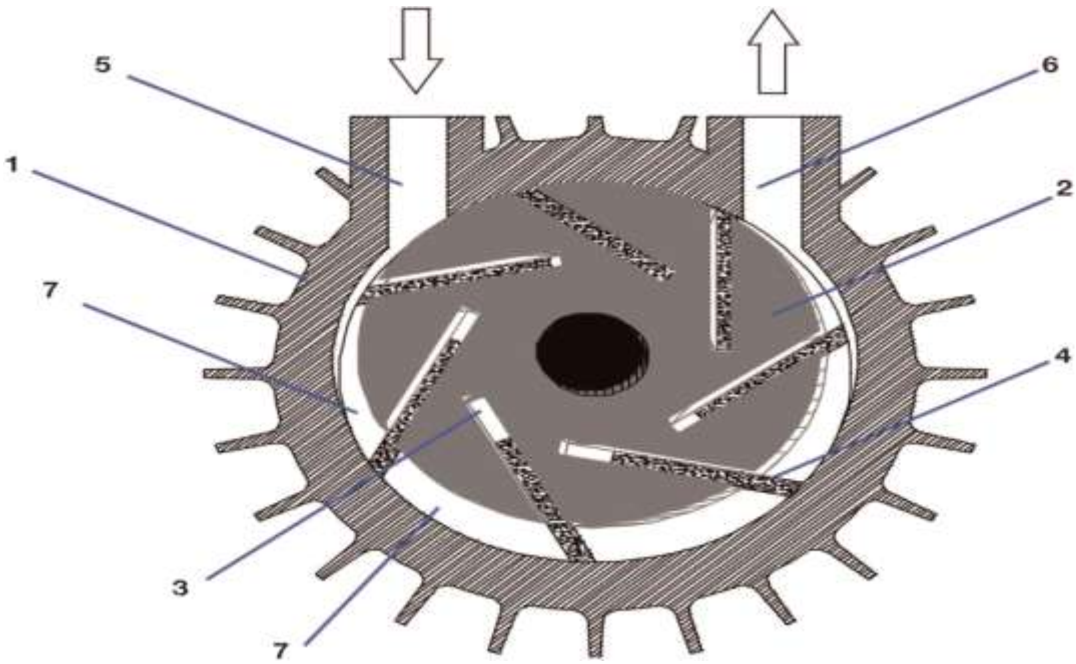
When the power source is connected to crank, the crank will start rotating and connecting rod also displaced along with crank. The piston connected to the connecting rod will move in linear direction. If crank moves outwards then the piston moves towards its right and create vacuum in the cylinder.

This vacuum causes suction valve to open and liquid from the source is forcibly sucked by the suction pipe

When the crank moves inwards or towards the cylinder, the piston will move towards its left and compresses the liquid in the cylinder. Now, the pressure makes the delivery valve to open and liquid will discharge through delivery pipe. When piston reaches its extreme left position whole liquid present in the cylinder is delivered through delivery valve. Then again the crank rotate outwards and piston moves right to create suction and the whole process is repeated.

Generally the above process can be observed in a single acting reciprocating pump where there is only one delivery stroke per one revolution of crank. But when it comes to double acting reciprocating pump, there will be two delivery strokes per one revolution of crank.

ROTARY VANE PUMP WORKING PRINCIPLE



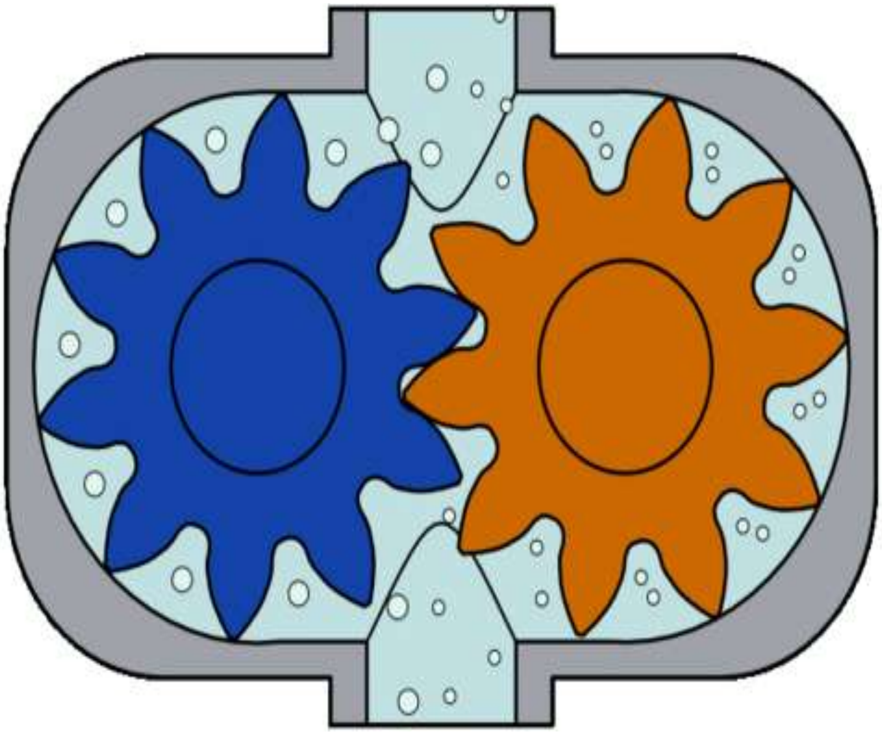
A rotor (2) is positioned eccentrically in the pump cylindrical housing (1). The free moving vanes (4) are inserted into a numerous rotor slots (3). When the rotor turns the centrifugal force throws the vanes against the cylindrical wall and creates a chamber between the rotor and the cylinder. As the rotor continues to turn the chamber volume between the blades keep changing due to the rotor positioned eccentrically. From the inlet (5) to outlet (6) The chamber volume (7) becomes bigger and then smaller.

When the volume gets bigger a vacuum is produced as a result from the rotation of the vanes making air entering the chamber from the inlet (5). When the chamber gets smaller due to the compressed air a pressure is produced at the outlet (6).

GEAR PUMP

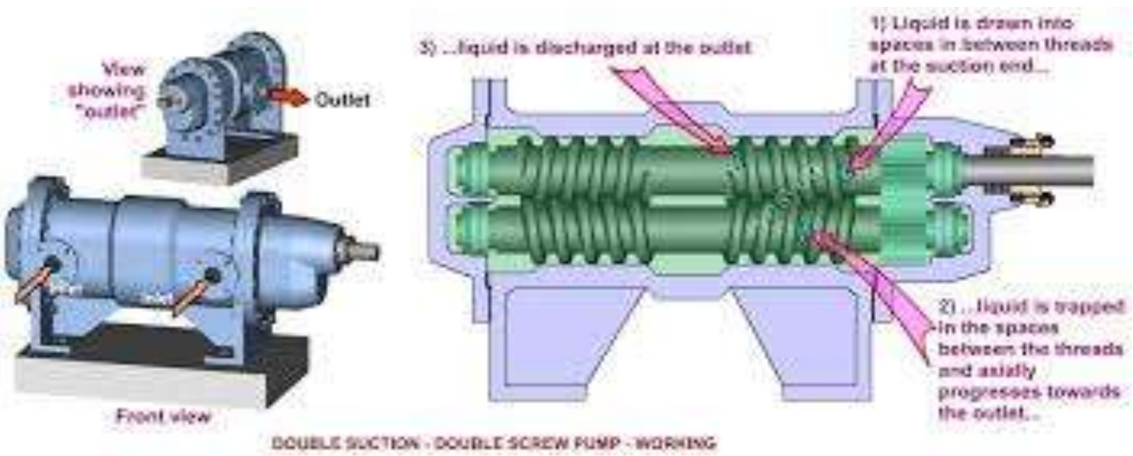
A gear pump uses the meshing of gears to pump fluid by displacement. They are one of the most common types of pumps for hydraulic fluid power applications. The gear pump was invented around 1600 by Johannes Kepler.

Gear pumps are also widely used in chemical installations to pump high viscosity fluids. There are two main variations: external gear pumps which use two external spur gears, and internal gear pumps which use an external and an internal spur gears (internal spur gear teeth face inwards, see below). Gear pumps are positive displacement (or fixed displacement), meaning they pump a constant amount of fluid for each revolution. Some gear pumps are designed to function as either a motor or a pump.



SCREW PUMP

A screw pump is a type of rotary pump which is equipped with screws that mesh together and rotate within a cylindrical cavity or liner. The fluid enters from the suction side of the pump and moves linearly along these intermeshing screws to the discharge side of the pump. The clearances between the screws and the liner are very small hence the fluid gains pressure while moving through the pump.

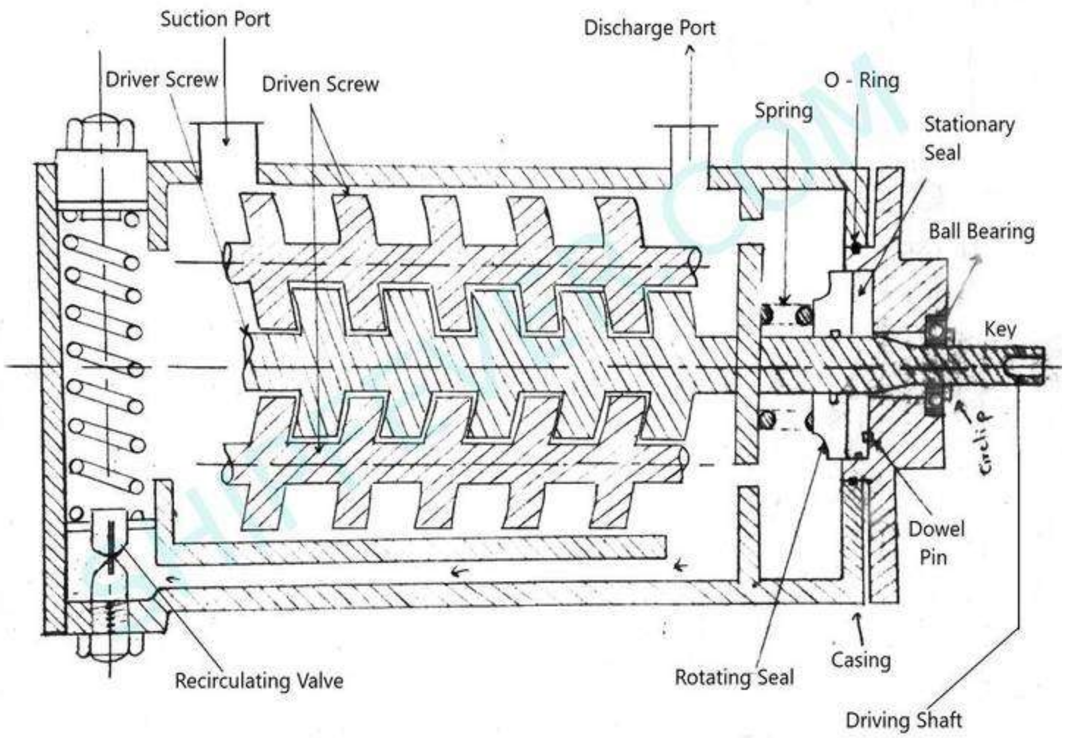


DOUBLE SUCTION - DOUBLE SCREW PUMP - WORKING

WORKING OF A SCREW PUMP

A Screw Pump is a type of Positive Displacement Pump. This means that it moves fluid by continually displacing the area that the fluid occupies. The screws are encased inside of a liner, usually made of some sort of metal. The fluid fits into the screw cavities within this liner and is forced through the pump and out of the discharge as the screws rotate and inter-mesh.

Since there needs to be some clearance between the liner and the screws, it is possible for any fluid that is pumped to slip backwards into the pump to lower pressure zones. For high viscosity fluids like this volumetric slippage is usually a non-issue. As the viscosity decreases, however, this slippage becomes substantial thus; reducing the efficiency of the pump. This has to be taken into consideration when pumping water or similar fluid, and particularly in multi-phase applications where vapor slugs are mixed into the fluid stream. In these cases, all the clearances within the pump must be minimized to reduce slip.



CENTRIFUGAL PUMP

Centrifugal pump is a hydraulic machine which converts mechanical energy into hydraulic energy by the use of centrifugal force acting on the fluid. These are the most popular and commonly used type of pumps for the transfer of fluids from low level to high level. Its is used in places like agriculture, municipal (water and wastewater plants), industrial, power generation plants, petroleum, mining, chemical, pharmaceutical and many others.

When a certain mass of liquid is made to rotate by an external source, it is thrown away from the centrifugal axis of rotation and a head is impressed which enables it to rise to a higher level. Centrifugal Pumps can be used for viscous and non-viscous liquids and has higher efficiency.

Main Parts of Centrifugal Pump

The Main parts of Centrifugal Pump are:

1. Impeller

   It is a wheel or rotor which is provided with a series of backward curved blades or vanes. It is mounded on the shaft which is coupled to an external source of energy which imparts the liquid energy to the impeller there by making it to rotate.

Open, Semi Enclosed and Enclosed Impeller.

Impellers are divided into 3 types,

1. Open Impeller
2. Semi enclosed Impeller
3. Enclosed Impeller

2. Casing

It is a pipe which is connected at the upper end to the inlet of the pump to the centre of impeller which is commonly known as eye. The double end reaction pump consists of two suction pipe connected to the eye from both sides. The lower end dips into liquid in to lift. The lower end is fitted in to foot valve and strainer.

Commonly three types of casing are used in centrifugal pump,

1. Volute Casing
2. Vortex Casing
3. Casing with Guide Blades

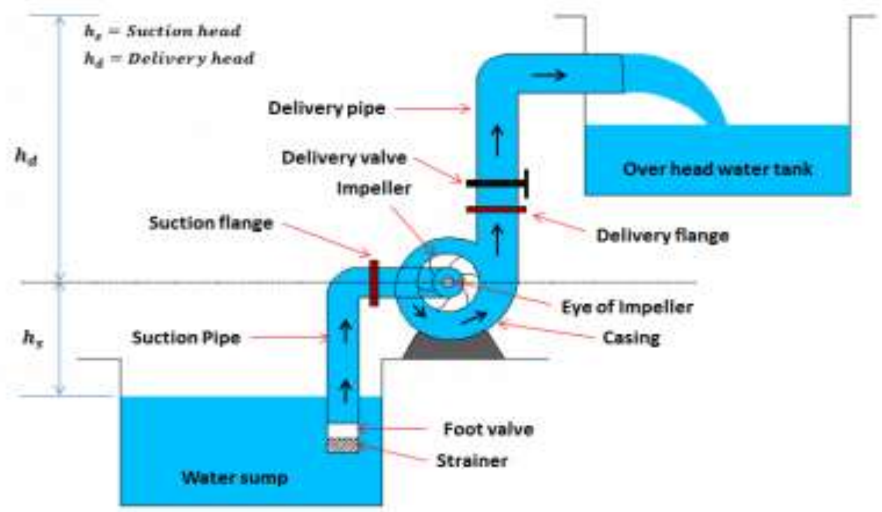
3. Delivery Pipe

It is a pipe which is connected at its lower end to the out let of the pump and it delivers the liquid to the required height. Near the outlet of the pump on the delivery pipe, a valve is provided which controls the flow from the pump into delivery pipe.

4. **Suction Pipe** with Foot Valve and Strainer

suction pipe is connected with the inlet of the impeller and the other end is dipped into the sump of water. At the water end, it consists of foot value and strainer. The foot valve is a one way valve that opens in the upward direction. The strainer is used to filter the unwanted particle present in the water to prevent the centrifugal pump from blockage.

WORKING OF CENTRIFUGAL PUMP



Centrifugal Pump Working

The first step in the operation of a centrifugal pump is priming. Priming is the operation in which suction pipe casing of the pump and the position of fluid with the liquid which is to be pumped so that all the air from the position of pump is driven out and no air is left. The necessity of priming of a centrifugal pump is due to the fact that the pressure generated at the centrifugal pump impeller is directly proportional to density of fluid that is in contact with it.

After the pump is primed the delivery valve is still kept closed and electric motor is started to rotate the impeller. The delivery valve is kept closed in order to reduce valve is opened the liquid is made to flow in an outward radial direction there by vanes of impeller at the outer circumference with high velocity at outer circumference due to centrifugal action vacuum is created.

This cause liquid from sump to rush through suction pipe to eye of impeller thereby replacing long discharge from center circumference of the impeller is utilized in lifting liquid to required height through delivery pipe.

APPLICATION OF CENTRIFUGAL PUMPS

- Oil & Energy – pumping crude oil, slurry, mud; used by refineries, power generation plants
- Industrial & Fire Protection Industry – Heating and ventilation, boiler feed applications, air conditioning, pressure boosting, fire protection sprinkler systems.
- Waste Management, Agriculture & Manufacturing – Wastewater processing plants, municipal industry, drainage, gas processing, irrigation, and flood protection
- Pharmaceutical, Chemical & Food Industries – paints, hydrocarbons, petro-chemical, cellulose, sugar refining, food and beverage production

CENTRIFUGAL PUMP TROUBLES AND REMEDIES

Troubles in centrifugal pumps can be grouped into two classes: mechanical troubles and hydraulic troubles. Mechanical troubles include breakage of the pump coupling or shaft. These troubles are easily traceable and can be attended to promptly. However, hydraulic troubles such as failure to deliver water, reduction in discharge and overloading of the prime mover are more difficult to rectify. The major troubles encountered in a centrifugal pump and their remedial measures are discussed below, which can serve as guidelines for the pump users.

SYMPTOM	PROBABLE FAULT	REMEDY
1. Pump does not deliver water	• Impeller rotating in wrong direction.	Reverse direction of rotation.
	• Pump not properly primed ¾ air or vapor lock in the suction line.	Stop pump and reprime.
	• Inlet of suction pipe insufficiently submerged.	Ensure adequate supply of liquid.

	• Air leaks in suction line or gland arrangement.	Make good any leaks or repack gland.
	• Pump not up to rated speed.	Increase speed.
2. Pump does not deliver rated quantity	• Air or vapor lock in the suction line.	Stop pump and reprime.
	• Inlet of suction pipe insufficiently submerged.	Ensure adequate supply of liquid.
	• Pump not up to rated speed.	Increase speed.
	• Air leaks in suction line or gland arrangement.	Make good any leaks or repack gland.
	• Foot valve or suction strainer choked.	Clean foot valve or strainer.
	• Restriction in delivery pipework or pipework incorrect.	Clear obstruction or rectify error in pipework.
	• Head underestimated.	Check head losses in delivery pipes, bends and valves, reduce losses as required.
	• Unobserved leak in delivery.	Examine pipework and repair leak.
	• Blockage in impeller or casing.	Remove half casing and clear obstruction.
	• Excessive wear at neck rings or wearing plates.	Dismantle pump and restore clearances to original dimensions.
	• Impeller damaged.	Dismantle pump and renew impeller.
	• Pump gaskets leaking.	Renew defective gaskets.
3. Pump does not generate its rated delivery pressure	• Impeller rotating in wrong direction.	Reverse direction of rotation.
	• Pump not up to rated speed.	Increase speed.
	• Impeller neck rings worn excessively.	Dismantle pump and restore clearances to original dimensions.
	• Impeller damaged or choked.	Dismantle pump and renew impeller or clear blockage.
	• Pump gaskets leaking.	Renew defective gaskets.

4. Pump loses liquid after starting	• Suction line not fully primed ¾ air or vapor lock in the	Stop pump and reprime.

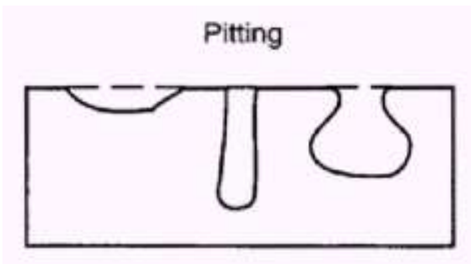
	suction line.	
	• Inlet of suction pipe insufficiently submerged.	Ensure adequate supply of liquid at suction pipe inlet.
	• Air leaks in suction line or gland arrangement.	Make good any leaks or renew gland packing.
	• Liquid seal to gland arrangement logging ring (if fitted) choked.	Clean out liquid seal supply.
	• Logging ring not properly located.	Unpack gland and relocate logging ring under supply orifice.
5. Pump overloads driving unit	• Pump gaskets leaking.	Renew defective gaskets.
	• Serious leak in delivery line, pump delivering more than its rated quantity.	Repair leakage.
	• Speed too high.	Reduce speed.
	• Impeller neck rings worn excessively.	Dismantle pump and restore clearance to original dimensions.
	• Gland packing too tight.	Stop pump, close delivery valve to relieve internal pressure on packing, slacken back the gland nuts and retighten to finger tightness.
	• Impeller damaged.	Dismantle pump and renew impeller.
	• Mechanical tightness at pump internal components.	Dismantle pump, check internal clearance and adjust as necessary.
	• Pipework exerting strain on pump.	Disconnect pipework and realign to pump.
6. Excessive Vibration	• Air or vapor lock in suction.	Stop pump and reprime.
	• Inlet of suction pipe insufficiently submerged.	Ensure adequate supply of liquid at suction pipe inlet.
	• Pump and driving unit incorrectly aligned.	Disconnect coupling and realign pump and driving unit.
	• Worn or loose bearings.	Dismantle and renew bearings.
	• Impeller chocked or damaged.	Dismantle pump and clear or renew impeller.
	• Rotating element shaft bent.	Dismantle pump and straighten or renew shaft.

	• Foundation not rigid.	Remove pump, strengthen the foundation and reinstall pump.
	• Coupling damaged.	Renew coupling.
	• Pipework exerting strain on pump.	Disconnect pipework and realign to pump.
7. Bearing overhauling	• Pump and driving unit out of alignment.	Disconnect coupling and realign pump and driving unit.
	• Oil level too low or too high.	Replenish with correct grade of oil or drain down to correct level.
	• Wrong grade of oil.	Drain out bearing, flush through bearings; refill with correct grade of oil.
	• Dirt in bearings.	Dismantle, clean out and flush through bearings; refill with correct grade of oil.
	• Moisture in oil.	Drain out bearing, flush through and refill with correct grade of oil. Determine cause of contamination and rectify.
	• Bearings too tight.	Ensure that bearings are correctly bedded to their journals with the correct amount of oil clearance. Renew bearings if necessary.
	• Too much grease in bearing.	Clean out old grease and repack with correct grade and amount of grease.
	• Pipework exerting strain on pump.	Disconnect pipework and realign to pump.
8. Bearing wear	• Pump and driving unit out of alignment.	Disconnect coupling and realign pump and driving unit. Renew bearings if necessary.
	• Rotating element shaft bent.	Dismantle pump, straighten or renew shaft. Renew bearings if necessary.
	• Dirt in bearing.	Ensure that only clean oil is used to lubricate bearings. Renew bearings if necessary. Refill with clean oil.
	• Lack of lubrication.	Ensure that oil is maintained at its correct level or that oil system is functioning correctly. Renew bearings if necessary.
	• Bearing badly installed.	Ensure that bearings are correctly bedded to their journals with the correct amount of oil clearance. Renew bearings if necessary.

	• Pipework exerting strain on pump.	Ensure that pipework is correctly aligned to pump. Renew bearings if necessary.
	• Excessive Vibration.	Refer to symptom 6.
9. Irregular delivery	• Air or vapor lock in the suction line.	Stop pump and reprime.
	• Fault in driving unit.	Examine driving unit and make good any defect.
	• Air leaks in suction line or gland arrangement.	Make good any leaks or repack gland.
	• Inlet of suction pipe insufficiently immersed in liquid.	Ensure adequate supply of liquid at suction pipe inlet.
10. Excessive noise level	• Air or vapor lock in suction line.	Stop pump and reprime.
	• Inlet of suction pipe insufficiently submerged.	Ensure adequate supply of liquid at suction pipe inlet.
	• Air leaks in suction line or gland arrangement.	Make good any leaks or repack gland.
	• Pump and driving unit out of alignment.	Disconnect coupling and realign pump and driving unit.
	• Worn or loose bearings.	Dismantle and renew bearings.
	• Rotating element shaft bent.	Dismantle pump, straighten or renew shaft.
	• Foundation not rigid.	Remove pump and driving unit, strengthen foundation.

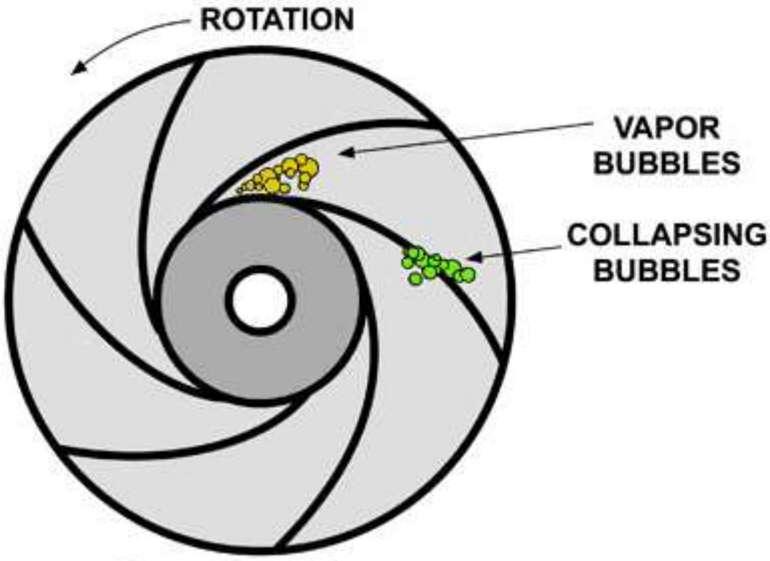
PITTING

The erosion of pump material on the inside surface due to the repeated hammering action caused by collapsing vapour bubbles at high pressure region is called pitting



CAVITATION

is a phenomenon in which rapid changes of pressure in a liquid lead to the formation of small vapor-filled cavities, in places where the pressure is relatively low.



Centrifugal Pump
Cavitation

When subjected to higher pressure, these cavities, called "bubbles" or "voids", collapse and can generate shock wave that is strong very close to the bubble, but rapidly weakens as it propagates away from the bubble.

PRIMING

The operation of filing the suction pipe, casing and a portion of delivery pipe (up to delivery valve) of the centrifugal pump from outside source with the liquid to be filled by pump before starting the pump is called priming in centrifugal pump.

Method of priming

1. Manual priming
2. Vacuum priming
3. Self-priming

TURBINES

Hydraulic turbines are machines which convert hydraulic energy into mechanical energy. If the machine transforms mechanical energy into hydraulic energy it is called a pump.

Thus in turbines, fluid does work on the machine and machine produces power, but the pump absorbs the power and work is done on the fluid.

The mechanical energy developed is utilized for running an electric generator which is directly coupled to the shaft of the turbine. The electric power developed by the electric generator is known as hydroelectric power.

So, the generation of hydroelectric power is cheaper than the other resources like coal, oil, etc.

In general, the principal component of a turbine is a rotor. The rotor is a wheel carrying a number of plates and vanes on its periphery.

The rotor is housed in a stationary casing and water possess a good amount of potential energy which is allowed to flow through pipes and finally discharged through nozzles and thus gaining kinetic energy.

Whenever the water strikes the runner and causes it to rotate, the mechanical energy developed is supplied to the generator coupled to the runner which generates electricity.

Classification of Hydraulic Turbines:

The hydraulic Turbines were classified according to the following conditions.

1. **According to types of energy at inlet**
2. **The direction of flow of water**
3. **Available head**
4. **Specific speed**

1. According to types of energy at inlet

Impulse: There is no pressure drop on the runner/rotor. K.E of water coming from the jet is used to run the runner/rotor.

Ex: Pelton wheel turbine.

Reaction: There is a loss of K.E as well as pressure energy on the runners of the blade.

Ex: Francis turbine

2. The direction of flow of water

If the water strikes the blades of the runner tangential to the path of rotation called Tangential flow.

Ex: Pelton wheel turbine.

Radial: If the water strikes the blades of the runner radially and coming out axially called as Radial flow.

Ex: Francis turbine

Axial: In this flow, the water flows parallel to the axis of the turbine.

Ex: Kaplan turbine

3. Available head

High head: The turbine capable of working under the high potential head of water above 300m

Ex: Pelton wheel turbine.

Medium head: The turbine is capable of working under a medium range of potential head about 60m to 300m

Ex: Francis turbine.

Low head: The turbine is capable of working under a low range of potential head less than 60m

4. Specific speed:

Low Specific Speed:

Turbine works in the range of 10-50. (Ex: Pelton wheel turbine)

Medium Specific Speed:

Turbine works in the range of 50-350. (Ex: Francis turbine)

High Specific Speed:

Turbine works in the range of 250-850. (Ex: Kaplan turbine)

This is the classification of Hydraulic Turbines in a detailed way.

THE DIFFERENCE BETWEEN IMPULSE TURBINE AND REACTION TURBINE IS AS FOLLOWS.

IMPULSE	REACTION
Available energy is converted into kinetic energy	A major part of available energy is converted to pressure energy
Pressure in the turbine is constant	Pressure gradually reduces while water flows on the turbine blades
The wheel and the blades should have accesses to free air and must not run fully.	The blades are always under the action of pressure, the wheel must always run fully.
Only one face of the blade is active	Both sides
Regulation of flow and power is easier without loss of energy	Difficult
Used for high heads	Low and medium heads
Efficiency is less	Efficiency is more
Energy transfer is a change in energy	Due to a change in pressure head

PELTON WHEEL TURBINE

This is the only impulse type of hydraulic turbine named after Lester A.Pelton, the American engineer. It is well suited for operating under high heads.

- The turbine capable of working under the high potential head of water is the Pelton Wheel Turbine which works on the head greater than 300 m.
- The runner consists of a circular disc with a suitable number of double semi-ellipsoidal cups known as buckets which are evenly spaced around its Periphery.
- One or more nozzles are mounted so that, each directs a jet along the tangent to the circle through the centers of the buckets called the Pitch Circle.
- A casing is provided only to prevent the splashing of water and for discharging the water to the tailrace.

COMPONENTS OF THE PELTON WHEEL TURBINE:

The Components of Pelton Wheel Turbine are as follows.

1. Penstock
2. Nozzle and Spear
3. Runner and buckets
4. Casing
5. Breaking Jet

The explanation of the above components is as follows.

1. Penstock:

It is a channel or pipeline which controls the flow of water or it also acts as directing medium for the fluid flow.

2. Nozzle and Spear:

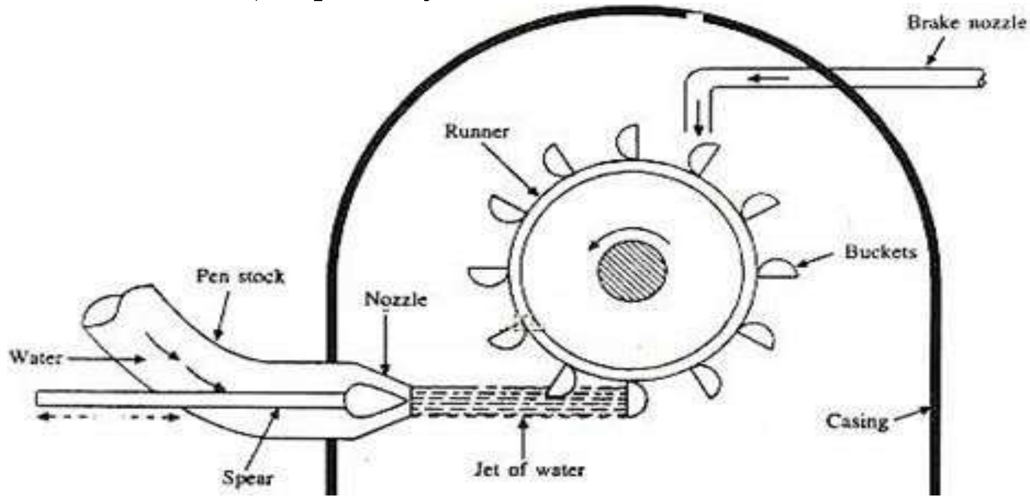
Nozzle:

The nozzle is used to increase the kinetic energy of water which is used to strike the buckets attached to the runner.

Spear: Spear is used to control the quantity of water striking the buckets. It is a conical needle installed inside the nozzle to regulate the water flow that is going to strike on the buckets or vanes of the runner. It is operated by a handwheel.

The rate of water flow increases and decreases when the spear is moved in a backward direction and forward direction respectively and that can be handled by means of a hand wheel(It is operated in the axial direction).

The setup of Spear along with nozzle is shown in the below figure.



4. Runner and buckets:

The runner with buckets is shown in the figure given above.

- The rotating part of the turbine is a runner which is a circular disc and on the periphery of which a number of buckets are evenly spaced.
- The buckets are made of two hemispherical cups joined together. The splitter acts as a wall joining two hemispherical cups which can splits the water into two equal parts(i.e.on to the hemispherical cups.) deflected through an angle of 160 degrees to 170 degree.
- The buckets of the Pelton turbine are made up of cast iron, cast steel bronze or stainless steel.

5. Casing:

The case (outer cover) in which turbine is placed so that water can not splash outside(surroundings) called casing. The Pelton turbine with the casing is shown in the figure given below.

- It also safeguard and helps the water to discharge to the trail race.
- In order to make the casing, Cast iron or fabricated steel plates are used.

6. Braking Jet:

- The spear is pushed in a forward direction into the nozzle so that there should be no water jet impinging onto the blades of the turbine and making the turbine to stop. but the runner keeps moving due to the inertia.
- To stop the runner in the shortest period of time, a small nozzle is provided which directs a jet of water at the back of the vanes and that stops the runner of the turbine called as breaking jet.

WORKING OF PELTON WHEEL TURBINE:

Water flows from the nozzle with high kinetic energy along the tangent to the path of the runner and when the jet of water comes in contact with the bucket, it exerts a force on the bucket called as Impulse force.

In order to control the quantity of water striking the runner, the nozzle fitted at the end of penstock is provided with a spear or needle fixed to the end of a rod.

In this process, the momentum of the water is transferred to the turbine. The impulse force produced due to this momentum of water causes the turbine to rotate.

The double Semi ellipsoidal buckets split the water jet into two halves which helps in balancing the wheel(runner). This ensures a smooth transfer of the fluid jet to the turbine wheel.

For maximum power and efficiency, the turbine is designed such that, the water Jet velocity is twice the velocity of the bucket.

ADVANTAGES OF A PELTON TURBINE:

- It is easy to maintain
- Intake and exhaust of water takes place at atmospheric pressure hence no draft tube is required
- No cavitation problem
- It has simple construction
- It can work on high heads and low discharge

DISADVANTAGES OF A PELTON TURBINE:

- It requires a high head for operation
- Its efficiency decreases quickly with time
- Turbine size is generally large
- Due to the high head, it is very difficult to control variations in the operating head.

FRANCIS TURBINE

Francis Turbine is a combination of both impulse and reaction turbine, where the blades rotate using both reaction. Francis turbine is used for the production of electricity in hydro power stations. There are two turbines flow patterns on which they work, namely radial and axial flow concepts.

The main reason of higher efficiency of Francis turbine is the design of blades; these blades rotate using both reaction and impulse force of water flowing through them. Due the use of this type of turbines the main problem faced due to the water head availability is eliminated as the turbine uses both the kinetic and potential energy to produce power.

For this, it is also known as Mixed Flow turbine.

THE MAJOR COMPONENTS OF FRANCIS TURBINE

1. Spiral Casing

Spiral casing is the inlet medium of water to the turbine. The water flowing from the reservoir or dam is made to pass through this pipe with high pressure. The blades of the turbines are circularly placed, which mean the water striking the turbines blades should flow in the circular axis for efficient striking.

To maintain the same pressure the diameter of the casing is gradually reduced, so as to maintain the pressure uniform, thus uniform momentum or velocity striking the runner blades

2. Guide Vanes

Guide vane guides the water to the runner blades. Stay vanes remain stationary at their position and reduces the swirling of water due to radial flow, as it enters the runner blades. Thus making turbine more efficient.

3. Runner Blades

The performance and efficiency of the turbine is dependent on the design of the runner blades. In a Francis turbine, runner blades are divided into 2 parts. The lower half is made in the shape of small bucket so that it uses the impulse action of water to rotate the turbine.

The upper part of the blades use the reaction force of water flowing through it. These two forces together makes the runner to rotate.

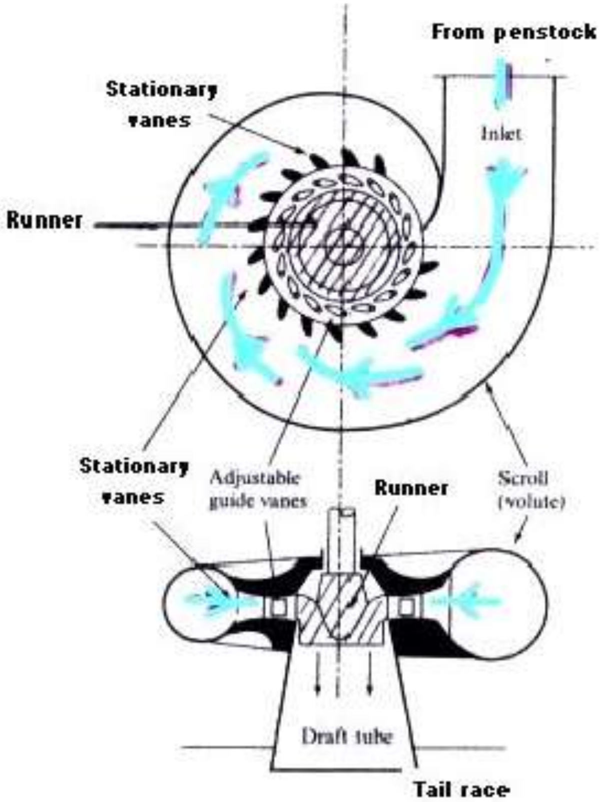
4. Draft Tube

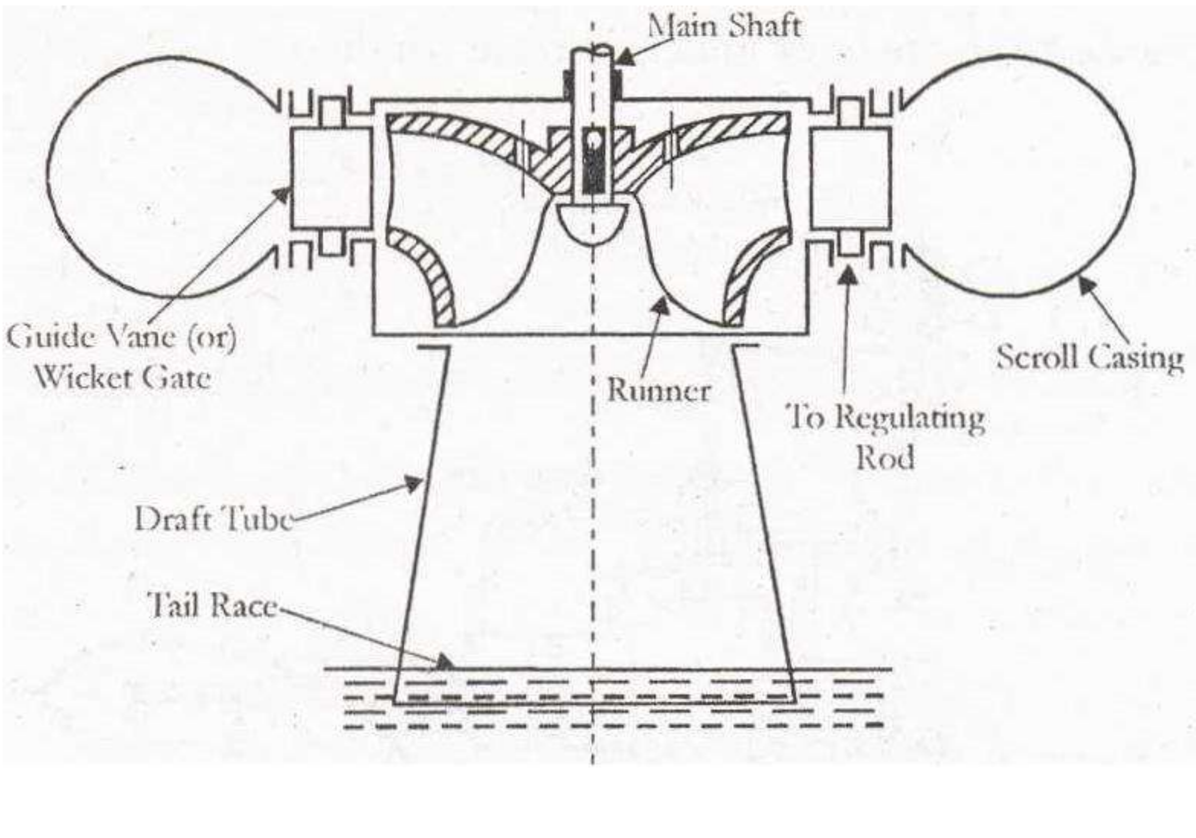
The pressure at the exit of the runner of Reaction Turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of turbine to the tail race.

This tube of increasing area is called Draft Tube. One end of the tube is connected to the outlet of runner while the other end is sub-merged below the level of water in the tail-race.

WORKING

Francis Turbine is a combination of both impulse and reaction turbine, where the blades rotate using both reaction and impulse force of water flowing through them producing electricity more efficiently. Francis turbine is used for the production of electricity in hydro power stations. Majorly there are two turbines flow patterns on which they work, namely radial and axial flow concepts. An American civil engineer by name, James B. Francis in Lowell, Massachusetts comes up with an idea of combining both impulse and reaction turbine where water enters the turbine radically and exits axially.



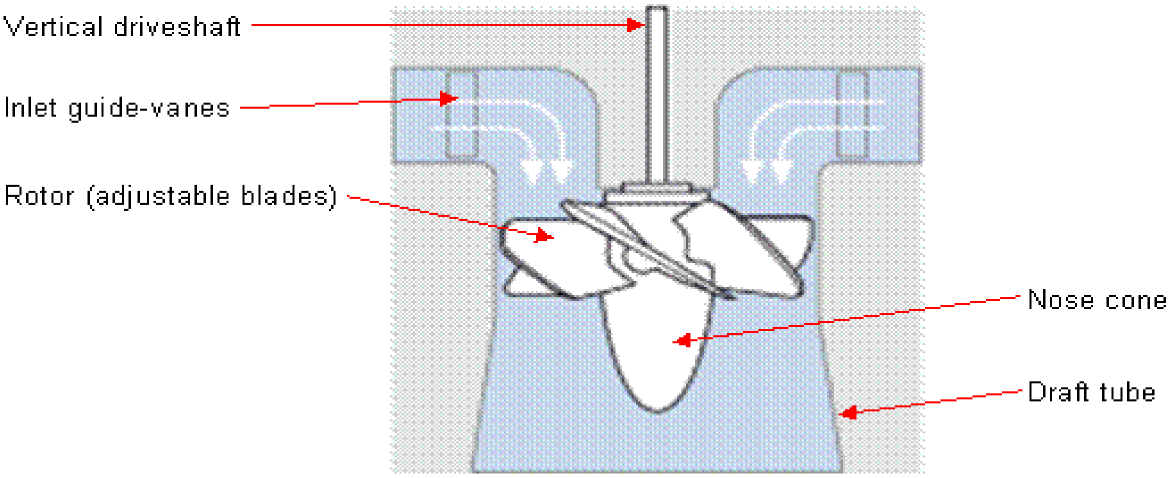


KAPLAN TURBINE

The Kaplan turbine is a propeller-type water turbine which has adjustable blades.

The Kaplan turbine was an evolution of the Francis turbine. I having efficient power production in low-head applications which was not possible with Francis turbines. The head ranges from 10–70 metres and the output ranges from 5 to 200 MW.

Kaplan turbines are now widely used throughout the world in high-flow, low-head power.



Kaplan Turbine works on the principle of axial flow reaction. In axial flow turbines, the water flows through the runner along the direction parallel to the axis of rotation of the runner. The water at the inlet of the turbine possesses both kinetic energy as well as pressure energy for effective rotation the blades in a hydro-power station.

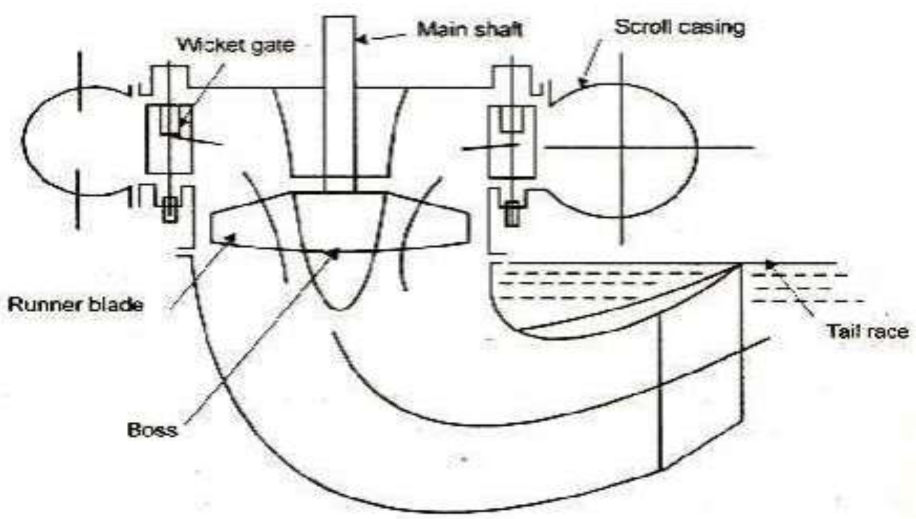


Figure: Kaplan turbine

1. Scroll Casing
It is a spiral type of casing that has decreasing cross section area. The water from the penstocks enters the scroll casing and then moves to the guide vanes where the water turns through 90° and flows axially through the runner. It protects the runner, runner blades guide vanes and other internal parts of the turbine from an external damage.

2. Guide Vane Mechanism
It is the only controlling part of the whole turbine, which opens and closes depending upon the demand of power requirement. In case of more power output requirements, it opens wider to allow more water to hit the blades of the rotor and when low power output requires it closes itself to cease the flow of water. If guide vanes is absent than the turbine can not work efficiently and its efficiency decreases.

3. Draft Tube
The pressure at the exit of the runner of Reaction Turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of turbine to the tail race. This tube of increasing area is called Draft Tube. One end of the tube is connected to the outlet of runner while the other end is sub-merged below the level of water in the tail-race.

4. Runner Blades
The heart of the component in kaplan turbine are its runner blades, as it the rotating part which helps in production of electricity.Its shaft is connected to the shaft of the generator. The runner of the this turbine has a large boss on which its blades are attached and the the blades of the runner is adjustable to an optimum angle of attack for maximum power output. The blades of the Kaplan turbine has twist along its length.

APPLICATION OF KAPLAN TURBINE

1. Kaplan turbines are widely used for electrical power production.
2. It can work efficiently at low water head and high flow rates as compared with other types of turbines.
3. It is smaller in size and easy to construct.
4. The efficiency of Kaplan turbine is very high as compares with other hydraulic turbine.

DISADVANTAGE OF KAPLAN TURBINE

1. The only disadvantage of kaplan turbine is cavitation, which occurs due to pressure drop in draft tube. Use of draft tube and proper material generally stainless steel for the runner blades may reduce the cavitation problem to a greater extent.

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(Prepared By: Ms. Promila , Assistant Professor , MED)

CHAPTER 6
OIL POWER HYDRAULIC AND PNEUMATIC SYSTEM

OIL POWER HYDRAULIC

OIL POWER HYDRAULIC is the branch of fluid mechanics which uses hydraulic oil as working medium.

PNUEMATIC is the branch of engineering which deals with the action of compressed air or any other gases in operating machines and equipment's.

MARITS AND DEMARITS OD USING OIL AS THE MEDIUM IN POWER TRASMISSION

Merits

1. Oil absorb vibration, and shock load
2. Oil control machine speed easily
3. Need less maintenance
4. Motion transmission by oil is not noisy
5. Oil powered machines are self-lubricated

Demerits

1. Leakage of oil cause problem in maintenance work
2. There are chance of fire hazards due to temperature rise of oil
3. Oil loses its viscosity under high temperature.
4. Cost of oil powered equipment's is more than the water powered equipment's.

APPLICATION OF OIL POWER HYDRAULICS

1. Operation of shaping machines.
2. Operation of press hammering
3. Hydraulic vise
4. Drilling operation

APPLICATION OF PNUMATIC SYSTEM

1. Pneumatic brakes in locomotives
2. Operating the blower
3. Operating the air motor
4. Pneumatic drill
5. Operating the spray gun.

BASIC COMPNENTS OF HYDRAULIC SYSTEM

1. Oil reservoir
2. Pumps
3. Valves
4. Filters
5. Seals

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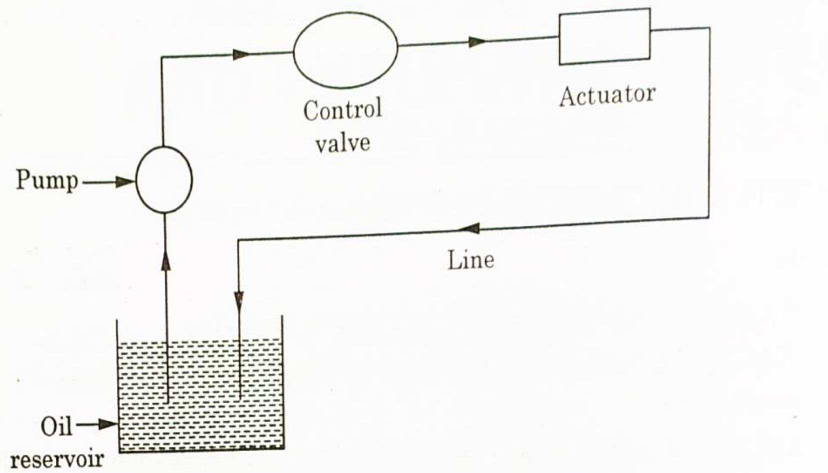

Fig. 7.1 : Basic Components of Hydraulic System

6. Pipe
7. Actuator

1. Oil Reservoir:
   Oil reservoir stores the oil which acts a working medium for the oil power hydraulic system. Oil is taken from the reservoir to different parts of the machine and it returns back to the reservoir after completing its function. The oil reservoir is usually kept at the bottom of the hydraulic system so that oil may flow back to the reservoir under the force of gravity.
2. Pump:
   Pump sucks the oil from the oil reservoir and delivers it to the hydraulic system under pressure. Pump is driven with the help of prime mover. 3.
3. Valves:
   Valves control the discharge, pressure and direction of oil to be pumped into the system. There are many types of valves which are used is oil power hydraulic system.
4. Filters:
   Filters separate the insoluble particles present in the oil. A coarse filter called strainer.
5. Seals:
   Seals are used to prevent the leakage of oil in the hydraulic system. 6. Pipe:
   Pipe is used to carry the oil power from one stage to another.
6. Actuator:
   Actuator receives the oil from the pump and converts the hydraulic energy into mechanical work.

HYDRAULIC OIL
Hydraulic oil transmits hydraulic energy in hydraulic system. Most common oil is petroleum based mineral oil. Besides transmitting energy it can perform following function.

1. LUBRICATION- To reduce friction lubricates various parts.

2. COOLING- it carries away heat generated in system
3. SEALING- It seals the moving parts to avoid leakage.
4. REMOVAL of CONTAMINANTS

TYPES OF HYDRAULIC OILS

1. MINERAL OILS-
   - Petroleum based oil.
   - These are economical and easily available
   - Best lubricating properties
   - Least corrosion problem

The only disadvantage is their flammability.so good at operating temperature below 50ºC.

2. EMULSION- is a mixture of two liquids which do not chemically react with each other. Emulsion of petroleum based oil and water is commonly used.
   There are two types of emulsion
   - OIL IN WATER EMULSION- are basically water based in which small droplets of oil is dispersed throughout the water phase. The limitation of these emulsion are poor viscosity which leads leakage and poor lubricating properties. However these problems are overcome by using additives. Such emulsion is used in high displacement, low speed pumps such as mining applications.
   - WATER IN OIL EMULSION- are basically oil based in which small droplets of water is dispersed throughout the oil phase. These having good viscosity and lubricating properties. These are good for operation at 25ºC because at high temperature, water evaporates and leads to the loss of fire resistant properties.

3. VEGITABLES OILS- Vegetables oils are biodegradable and environment friendly, possess good lubrication properties, moderates viscosity and less expensive.

   PROPERTIES OF IDEAL HYDRALIC OIL
   1. ideal viscosity
   2. good lubrication properties
   3. Good chemical and environment stability
   4. Incompressibility
   5. Fire resistant
   6. Low flammability
   7. Foam resistant
   8. Low volatility.
   9. Good heat dissipation ability
   10. Low density

SEALS

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Seals are material which is used in hydraulic system to prevent leakage of oil. Seal maintains the working pressure inside the system.

ADVANTAGE OF SEAL IN HYDRALIC SYSTEM
1. Increase in efficiency.
2. Prevention of loss of power
3. Prevention of failure of components such as valves etc.

CLASSIFICATION OF SEALS
1. Positive and non-positive seal
2. Static and Dynamic seal

Positive and non-positive seal:
Positive seal are those which do not permit any leakage of oil.
Non-Positive seal are those which permit small amount of leakage of oil to the extent of providing lubricating film on rotation parts.

Static and Dynamic seal:
Static seals are those which are used to prevent leakage of oil through stationery surface.

Dynamic seals are those which are used to prevent leakage of oil arount rotating or moving parts.

COMMONLY USED SEAL MATERIALS
1. Leather
2. Metal
3. Asbestos
4. Rubber, elastomer and plastics

1. **LEATHER**
   Leather is commonly used seal material in hydraulic system both static and dynamic seals.it is inexpensive. Seal of leather having following properties
   Low coefficient of friction
   High resistance to wear and abrasion
   Good lubricating properties
2. **METAL**
   Metal are good sealing material at high temperature and high pressure system.
3. **ASBESTOS**
   These seals are used for high temperature applications. However, use of these seals is limited being unhygienic for environment.

4. **RUBBER, ELASTOMER AND PLASTICS**
   These are commonly used sealing materials due to following reason
   1. Wide temperature range

2. Excellent resistance
3. Wide availably
4. Easy fabrication

SIMPLE VISUAL CHECKS OF OIL

The following characteristics may change during the service life of oils:

I. Visual appearance.
2. Smell.
3. Viscosity.
4. Tardiness.
5. Oxidation.
6. Acidity.
7. Foaming.
8. Water content.
9. Solid content.

It should be noted that in the modern hydraulic system, continuous monitoring of oil is must to maintain a safe hydraulic system. The following visual checks should be carried out during routine maintenance of hydraulic systems in order to determine the oil health.

1. Appearance: The oil should be inspected visually to see whether it is clear and bright or hazy and cloudy which may indicate water contamination, suspended material etc. A milky oil indicates that it is aerated and contains more air than the maximum of 8% by volume. In such situation, the system should by kept idle for long to allow the oil to settle inside the reservoir. It not much change is observed, there is no other alternative, but to change the entire oil.

2. Color: A dark color of oil indicates oxidation or excessive contarnination. However, the appearance and color of oil may be dependent upon the type of service to which oil is subjected.

3. Odour: Used oils normally have a bland or oily ordour.

CAUSES CONTAMINATION

Contamination enters the hydraulic system in the following ways:

1. These are present in the new system due to insufficient cleaning of components or part, of the system.
2. These are generated during the manufacturing and/or assembly of the system.
3. Fluid used to fill a hydraulic system may have contaminants.
4. Contaminants are generated by the chemical breakdown of hydraulic fluid.
5. Contaminants are generated whenever cavitation occurs in a hydraulic system.
6. The system may ingest air borne contaminants particularly through air breathers and cylinder rod seals.
7. Contaminants are introduced when a system is opened or closed during servicing and/or maintenance.

PROBLEMS CAUSED BY CONTAMINATION

Contamination causes following problems in the hydraulic system:

1. Rapid wears of components/parts resulting in decrease in system performance.

2. Sluggish operation and seizure of moving parts.
3. Leakage due to damage of seals.
4. Rapid oxidation of hydraulic fluid resulting in low fluid lite.

PREVENTIVE MEASURES OF CONTAMINATION

There are many measures which help to reduce the entry and adverse effects of contaminant, in the system:

1. Use pipes, tubing and fitting's which are free from rust, dirt, scale etc. in the hydraulic system
2. Flush the entire hydraulic system with the same type of fluid to be used before the start of normal operation.
3. Filter the hydraulic fluid before using to minimize entry of contaminants in the system.
4. Locate filters in the hydraulic system where they can provide most effective protection,
5. Provide continuous protection from the air borne contamination by sealing the hydraulic system. 6. Minimize source of water entry into the hydraulic system.
7. Maintain fluid viscosity and pH level.
8. Clean or replace filter elements on routine basis.
9. Avoid introducing thread sealants into the fluid stream.
10. Use non-corroding piping.

BASIC COMPONENTS OF PNEUMATIC SYSTEM

The basic components of a pneumatic system are shown in fig.

Basic Components of Pneumatic System

1. **Air Compressor**: An air compressor is a machine which is used to compress air at a desired pressure. Air from atmosphere is sucked by the air compressor. It is then compressed to the desired pressure. This high pressure air is delivered to the storage tank from where it is further delivered to the place of requirement with the help of pipeline. Air compressor is driven by an electric motor or diesel engine.
2. **Relief Valve**: The function of the relief valve is to release the pressure when the pressure of compressed air becomes greater than the allowable limit. In this way, relief valve keeps the system safe.
3. **Air Filter**: Air filter is used to separate dirt and dust- from the air. It prevents the entry of solid particles into the pneumatic system. Also it condenses and removes water vapours present in the air passing through it.
4. **Air Pressure Regulator**: An air pressure regulator is used to keep the air pressure constant to the pneumatic system.
5. **Lubricator**: Lubricator is used to produce the mist of oil and air. The mist so formed provides lubrication to the mating components of valves, cylinders etc.

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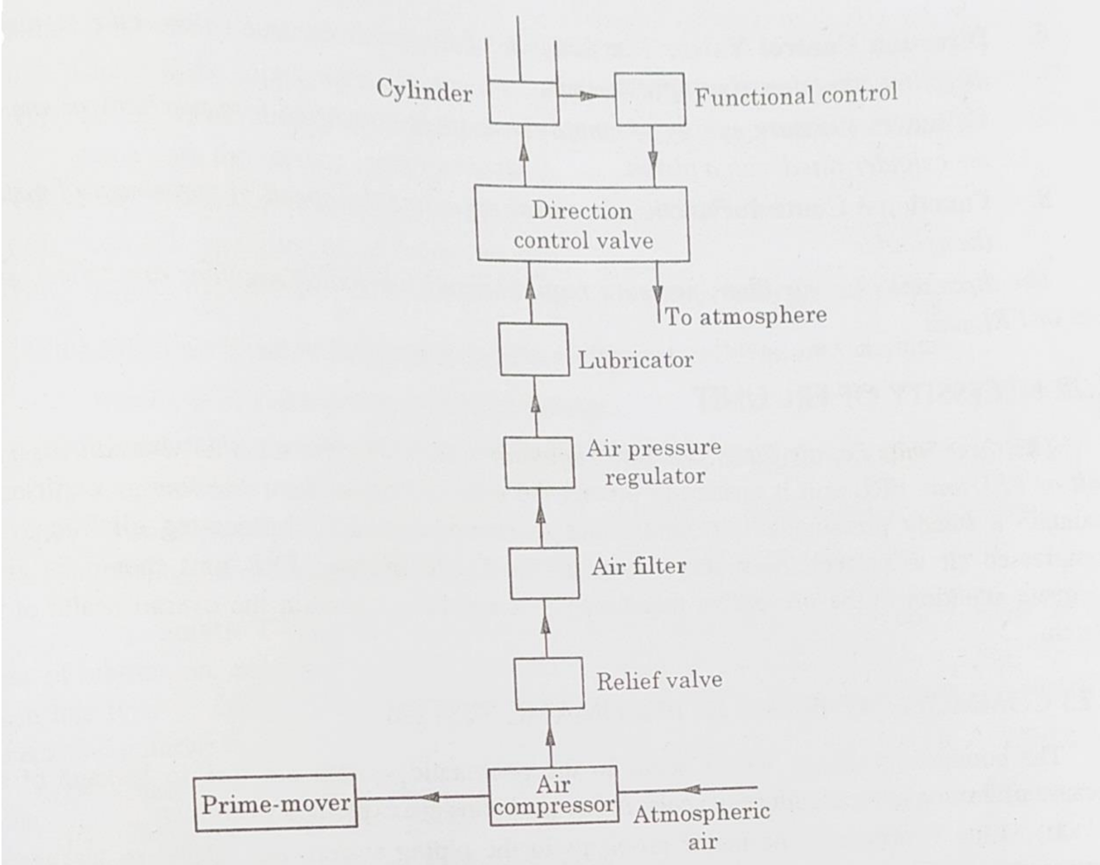

Fig. 7.2 : Basic Components of Pneumatic System

6. Direction Control Valve: The function of direction control valve is to regulate the direction of motion of compressed air.
7. Cylinder: pressure energy of compressed air is converted into mechanical energy in the cylinder, fitted with a piston.
8. Functional Control: Functional control regulates the speed of movement of piston in the cylinder.
The three unit's i.e, air filter, pressure regulator and lubricator together are called service unit or FRL unit.

NECESSITY OF FRL UNIT
The three unit's i.e, air filter, pressure regulator and lubricator together are called service unit or FRL unit. FRL unit is needed to protect the system from undesirable foreign particles, to maintain a steady pressure of air supply and to ensure a mist of lubricating oil film to the compressed air to protect the system from failure due to friction. FRL unit should be given adequate attention in the preventive maintenance schedule to maintain the overall health of the system.

COMMON PROBLEMS IN PNEUMATIC SYSTEM
The common problems which occur in the pneumatic system are due to leakage of air because of loose glands or failure of seals. A few problems are explained as follow:

1. **Line Problems**: The major problems in the piping system are related to leakage of compressed air. Leakage through pipeline fittings and glands is a routine problem. Leakage is caused due to loose joints or glands which require to be tightened at regular intervals to stop leakage.
   The following problems may occur due to leakage of compressed air:
   (1) Increased load on the air compressor.
   (2) Wastage of costly compressed air without serving any useful purpose.
   (3) Higher operating and maintenance cost of air installation plant.
   (4) Risk of product rejection, etc.

   Leakage can be prevented by adopting the following steps:
   (1) Tighten loose joints, fittings and glands.
   (2) Replace faulty and damaged fittings, ruptured pipes and hoses.
   (3) Use commercial bonding compounds available in the market.

2. FRL Unit: To maintain the overall health of it pneumatic system, the FRI, unit should be given adequate attention. The following steps

1) Clean the filler cartridge at regular interval Of time with kerosene or tri-thloro-ethylene.
2) Drain of The accumulated water and other foreign particles from the filter bowl.
3) Look for any external damage to the regulator.
4) Check if the supply of pressure air is steady or not. Pressure limits should be tested.
5) Count the number of oil drops •per minute to ensure proper lubrication and compare the Same with the service recommendation.
6) Maintain the oil level if it goes below the permissible level.
7) Use only specified oil as recommended.
8) Inspect the color of oil in the bowl and if the colour turns greyish, replace the oil.

If the FRL, unit is not of the proper type, the following problems may occur:

1. Blockage of valve points and other passages.
2. Undesirable wear of elements due to abrasive particles.
3. Corrosion of pipes and other valves due to water.
4. Formations of gum like substances due to break down of oil.
5. Formation of weak acids or electrolytes causing galvanic corrosion.

3. Pneumatic Components: Major reasons of failure of pneumatic components are dirt, Lack of lubrication, damaged seals etc. Hence if the FRL unit is maintained in a good condition,
Then this type of failure does not occur. For a normal system, the following points should be Checked regularly:

1. Check cylinders and valves.
2. Check for general cleanliness.
3. Check for wear and tear of mechanical parts.
4. Check whether the pipeline is in good condition or not.
5. Check whether return spring is safe.

4. Other Problems: Sometimes, a pneumatic system fails due to mechanical troubles
From other associated mechanical components or electrical systems. Now-a-days, more and more
Solenoid operated valves are in use. Hence, electrical failure may stop the operation of the system.

MAINTENANCE SCHEDULE OF PNEUMATIC SYSTEM

For periodic checkup and inspection of pneumatic system, the following parts of the Pneumatic system must be given more importance:

1. Air mains, lines and fittings.
2. FRL, unit.
3. On and off valve in line.
4. Pneumatic cylinders and air motors.
5. Pneumatic control valves.
6. Mechanical drive elements.
7. Pneumatic accessories and other associated elements.

1. AIR MAINS, LINES AND FITTING

Sr.no	NAME OF WORK	PERIODICITY
1	Condensate taps	Daily
2	Airlines, cuts in lines and holes	Weekly
3	Detection and arrest of air leakage	Monthly
4	Inspection of union, bends, tees , elbow, coupling etc.	Once in a month
5	Pressure rating in strategic points	Once in three months
6	Automatic draining of condensate	Once in three months
7	Through inspection of complete line system	Once in a year

2. FRL UNIT

Sr.no	NAME OF WORK	PERIODICITY
1	Detection and arrest of air leakage	Daily

2	Drain condensate from filter	Daily
3	Top up oil level	Weekly
4	Pressure rating and pressure regulator	Monthly
5	Arrest leakage of oil	Once in three months
6	Cleaning of filter cartridge	Half yearly
7	Calibrate pressure gauge	Half yearly
8	Clean up oil jet passage	Half yearly
9	Clean filter bowl	Yearly
10	Adjust oil jet	As per need

3. ON AND OFF VALVE

Sr. no.	Name of work	Periodicity
1	Actuating handle of valve	Weekly
2	Leakage of air through valve and hose fitting	Monthly
3	Overhauling if possible	Yearly

4 PNEUMATIC CYLINDERS AND AIR MOTOR

Sr.no	NAME OF WORK	PERIODICITY
1	Inspect the cylinder for force and speed accuracy	Weekly
2	Mechanical damage of piston rod	Weekly
3	Check RPM of motor	Weekly
4	Check torque of motor	Weekly
5	Check vibration produced by motor	Weekly

6	Check leakage and its arrest	Monthly
7	Check the tie rod tensions	Half yearly

4. PNEUMATIC CONTROL VALVES

Sr.no	NAME OF WORK	PERIODICITY
1	Possible air leakage and its arrest	Monthly
2	Check solenoid and its electrical parameters	Monthly
3	Check possible seal failure	Half yearly
4	Inspect actuating elements	Half yearly
5	Check valve adjustment	Half yearly
6	Check spring and valve actuator	Yearly or earlier if dismantled due to contingency
7	Mechanical damage to valve and there parts	Yearly or earlier if dismantled due to contingency

MECHANICAL DERIVE SYSTEM AND OTHER PNEUMATIC ACCESSORIES

Sr.no	NAME OF WORK	PERIODICITY
1	Mechanical links to power source for looseness etc	Monthly
2	Mechanical alignment	Half yearly
3	Inspect silencers	Half yearly
4	Check guide for mechanical motion	Half yearly