STUDY MATERIAL

HYDRAULIC MACHINES

&

INDUSTRIAL FLUID POWER

(FOR DIPLOMA & POLYTECHNIC STUDENTS)

5TH SEMESTER

Ch – 01 HYDRAULIC TURBINES

Introduction:

Hydraulic machines are defined as those machines which convert either hydraulic energy into mechanical energy (which is further converted to electrical energy) or mechanical energy into hydraulic energy.

Hydraulic machines are of two types : Turbines & Pumps

Turbines:

Turbines are defined as the hydraulic machines which convert hydraulic energy into mechanical energy. This mechanical energy is used in running an electric generator which is directly coupled top the shaft of the turbine. Thus mechanical energy is converted into electrical energy. The electrical power which is obtained from the hydraulic energy is known as Hydro-electric power.

- **Classification of Hydraulic turbine**

Hydraulic Turbines are classified as follows :

1. According to the type of energy at inlet

a. Impulse turbine – The energy available at inlet is only kinetic energy
- Requires high head and small quantity of flow.

b. Reaction turbine – The water posses kinetic energy as well as pressure energy at the inlet
- Requires low head and high quantity of flow.

2. According to the direction of flow of water through runner

a. Tangential Flow Turbine – Water flows along the tangent of the runner – (Pelton turbine)

b. Radial flow turbine – Water flows in the radial direction through the runner (No more used)

c. Axial flow turbine – Water flows through the runner along the direction parallel to the axis of rotation of the runner – (Kaplan turbine)

d. Mixed flow turbine (radial & axial) – Water flows through the runner in the radial direction but leaves in the direction parallel to axis of rotation of runner. – (Francis turbine)

3. According to the head at the inlet of turbine

a. High head turbine

b. Medium head turbine

c. Low head turbine

4. According to the specified speed of turbine

a. Low specific speed turbine – work under high head and low discharge condition.

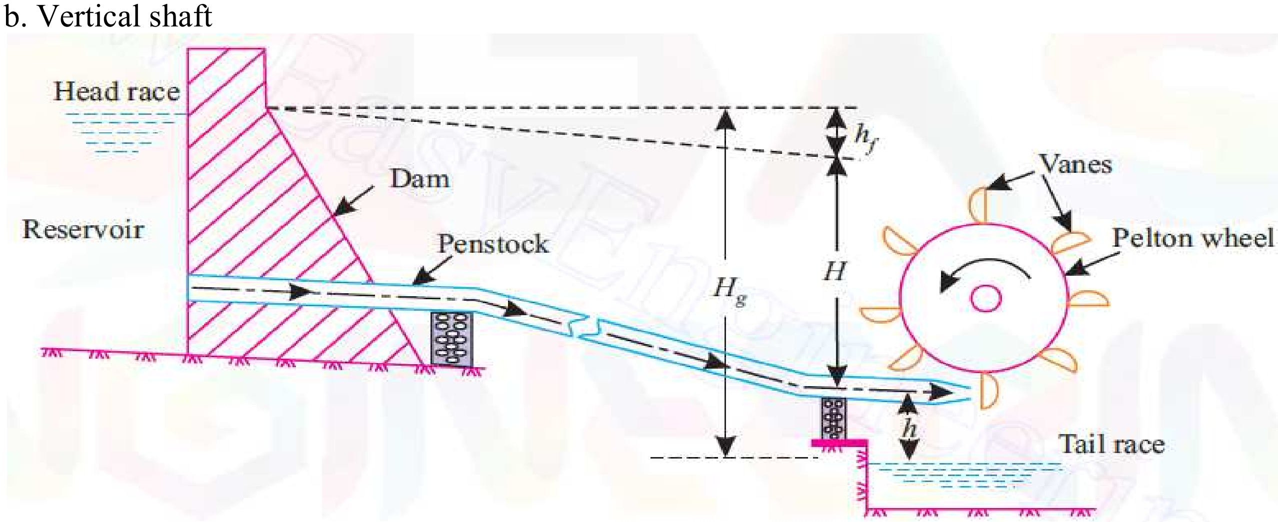
b. Medium specific speed turbine

c. High specific speed turbine - work under low head and high discharge condition.

5. According to the deposition of the turbine shaft

a. Horizontal shafts – Pelton turbines

b. Vertical shaft



Definitions of heads & Efficiencies of a turbine :

1. Gross Head : The difference between the head race level & tail race level when no water is flowing is known as gross head (H_g)

2. Net or Effective Head : It is defined as the head available at the inlet of the turbine. It is denoted by H. When water is flowing, a loss of head due to friction between the water & penstocks occurs.

So net head = $H_g - h_f - h$

H_g = gross head

h_f = head loss due to friction = $4fLv^2 / 2gD$

Where v = velocity of flow in penstock

L = Length of penstock

D = Diametre of penstock

3. Power developed by Runner = $\omega\, Q_a\, H_r$ Where, Runner head, $H_r = \frac{1}{g}(v_{w1} + v_{w2})u$

$$= \omega\, Q_a \times \frac{1}{g}(v_{w1} \pm v_{w2})u$$

Power supplied at inlet of turbine = Water power = $\omega\, Q_a\, H$

Power available from water jet = $\omega\, Q\, H$

Shaft power = Power available at turbine shaft = P

4. Efficiencies of a turbine :

The important efficiencies of a turbine are

a. Hydraulic efficiency

b. Mechanical efficiency

c. Volumetric efficiency

d. Overfal Efficiency

(a) Hydraulic efficiency (η_h) : It is the ratio of power developed by the runner to the power supplied at inlet of turbine.

Mathematically, $\eta_h = \frac{Power\ developed\ by\ the\ runner}{Power\ supplied\ at\ the\ inlet\ of\ turbine} = \frac{Runner\ Power}{Water\ Power}$

$$= [\omega\, Q_a \times \frac{1}{g}(v_{w1} \pm v_{w2})u] / [\omega\, Q_a\, H] = [(v_{w1} \pm v_{w2})u] / gH$$

Or $\eta_h = 2[(v_{w1} \pm v_{w2})u] / v_1^2$ as $v_1 = \sqrt{2gH}$

(b) Mechanical efficiency (η_m) : It is defined as the ratio of power obtained from the shaft of turbine to power developed by the runner.

Mathematically, $\eta_m = \frac{Power\ available\ at\ turbine\ shaft}{Power\ developed\ by\ the\ runner} = \frac{Shaft\ Power}{Runner\ Power}$

$$= P / [\omega\, Q_a \times \frac{1}{g}(v_{w1} \pm v_{w2})u]$$

- For Pelton Turbine, it lies between 0.97 – 0.99.

(c) Volumetric efficiency (η_v) : It is the ratio of volume of water actually striking the runner to the volume of water supplied by the jet to the turbine.

Mathematically, $\eta_v = \frac{Volume\ of\ water\ actually\ striking\ the\ runner}{Volume\ of\ total\ water\ supplied\ by\ jet\ to\ turbine} = Q_a / Q$

For Pelton turbines, $\eta_v = 0.97 - 0.99$

(d) Overal Efficiency (η_o) : it is the ratio of power available at the turbine shaft to the power supplied by water jet.

Mathematically, $\eta_v = \frac{Shaft\ power}{Power\ available\ from\ water\ jet} = P / \omega\, Q\, H$

For Pelton wheel, $\eta_o = 0.85 - 0.90$

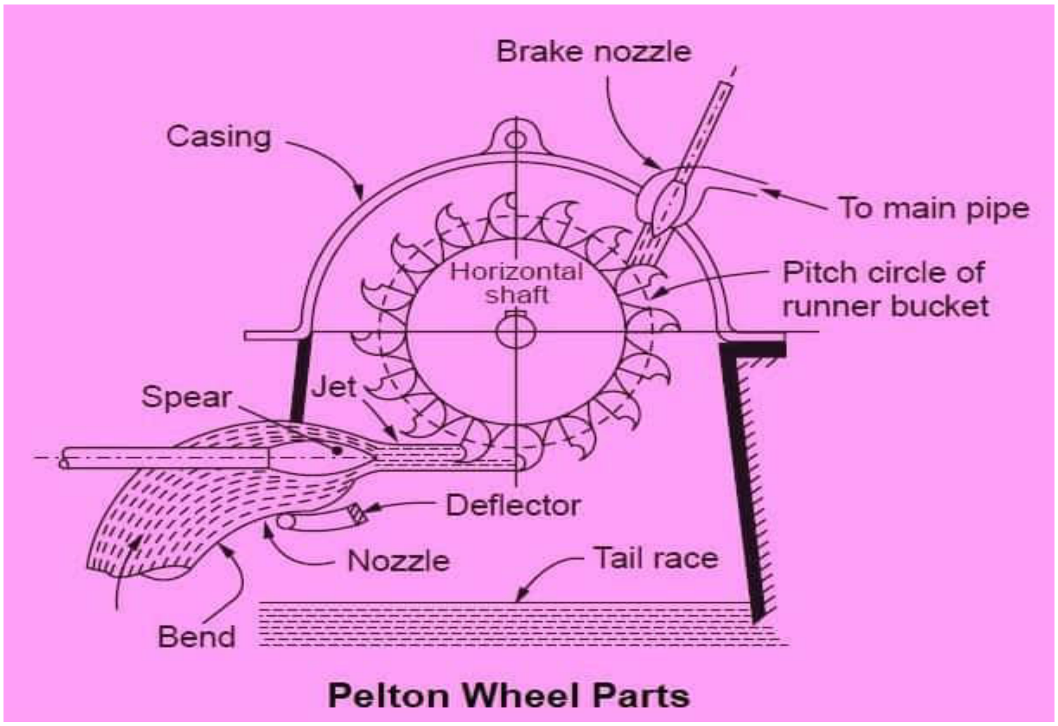
$$\eta_o = \eta_h . \eta_m . \eta_v$$

Construction of Pelton Wheel or Turbine :

Parts of Pelton Turbine :

The main components of a Pelton turbine are:

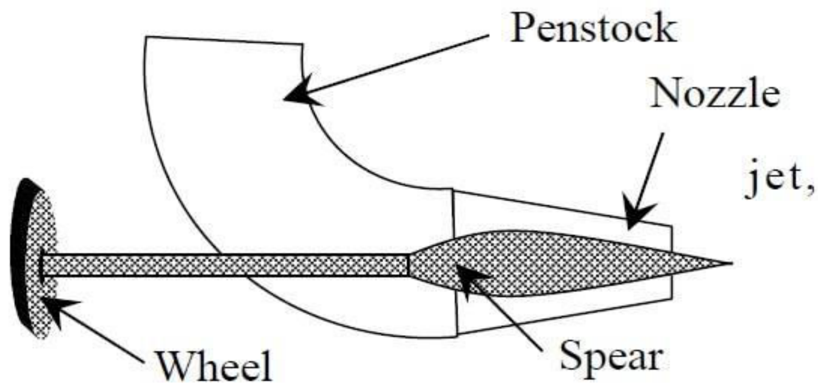
1. Nozzle and Flow Regulating Arrangement
2. Runner with Buckets
3. Casing
4. Breaking Jet.



Pelton wheel parts Diagram

1. Nozzle and flow regulating arrangement :

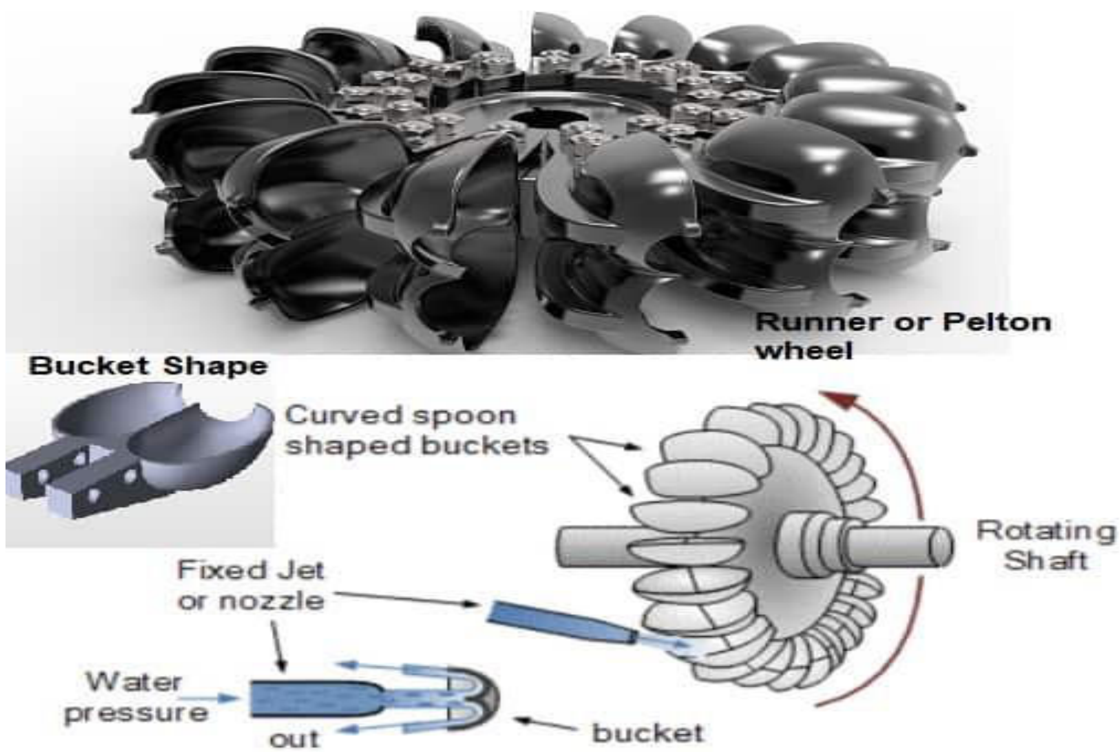
- Water is brought to the hydroelectric plant site through large penstocks at the end of which there will be a nozzle, which converts the pressure energy completely into kinetic energy. This will convert the liquid flow into a high-speed which strikes the buckets or vanes mounted on the runner, which in turn rotates the runner of the turbine.
- The amount of water striking the vanes is controlled by the forward and backward motion of the spear.
- The spear is a conical needle which is operated either by a hand wheel or automatically in an axial direction depending upon the size of the unit.



- When the spear is pushed forward into the nozzle the amount of water striking the runner is reduced. On the other hand, if the spear is pushed back, the amount of water striking the runner increases.

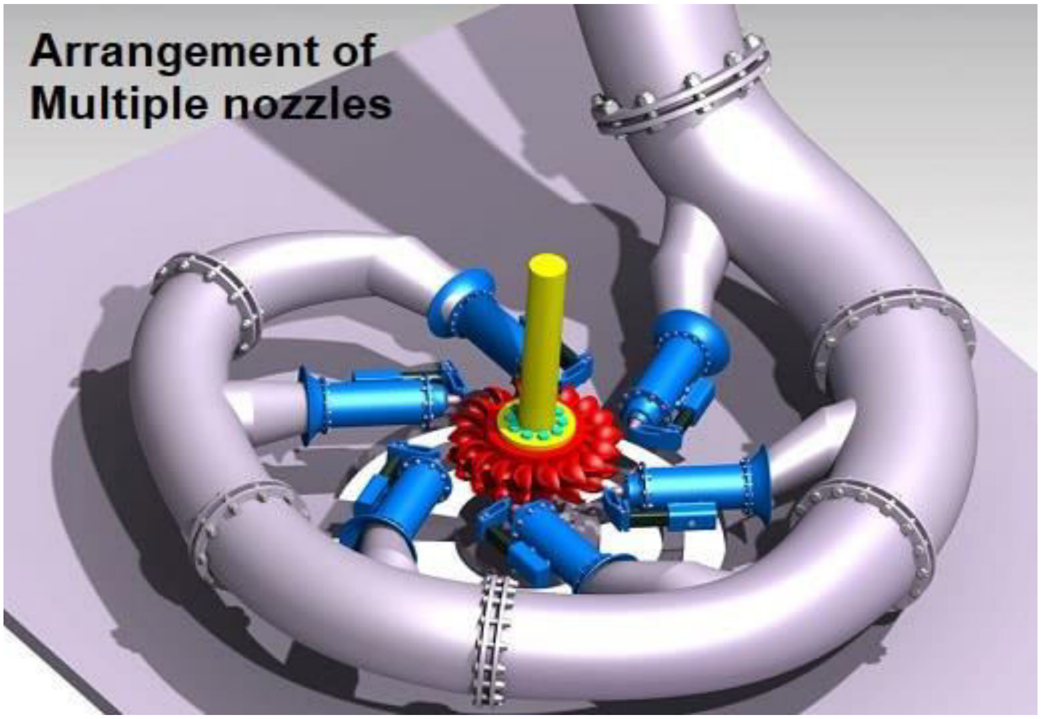
2. Runner with Buckets :

- Runner is a circular disk mounted on a shaft on the periphery of which several buckets are fixed equally spaced as shown in Fig.
- The buckets are made of cast -iron cast -steel, bronze, or stainless steel depending upon the head at the inlet of the turbine.
- The shape of the bucket is of a double hemispherical cup or bowl. Each bucket is divided into two symmetrical parts by a dividing wall which is known as the splitter.



Configuration of water flow in buckets

- The jet of water strikes on the splitter. the splitter divides the jet into two equal parts and the jet comes out at the outer edge of the bucket.
- The water jet strikes the bucket on the splitter of the bucket and gets deflected through (ɑ) 160-170°.
- **Arrangement of jets-** In most of the Pelton wheel plants, a single jet with a horizontal shaft is used. The number of the jets adopted depends upon the specific speed required.



3. Casing :

- It is made of cast -iron or fabricated steel plates. The main function of the casing is to prevent the splashing of water and to discharge the water into the tailrace.
- Casing is also acting as a safeguard against accidents.
- It is made of cast iron or fabricated steel plates. The casing of the Pelton wheel does not perform any hydraulic function.

4. Breaking jet:

- Even after the amount of water striking the buckets is completely stopped, the runner goes on rotating for a very long time due to inertia.
- To stop the runner in a short time, a small nozzle is provided which directs the jet of water on the back of the bucket with which the rotation of the runner is reversed. This jet is called as breaking jet.

5. Governing mechanism:

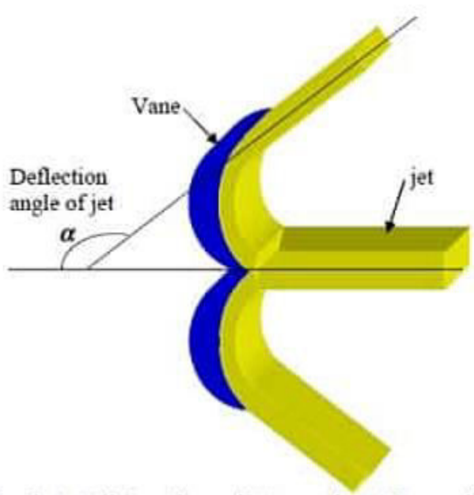
- The speed of the turbine runner is required to be maintained constant so that the electric generator can be coupled directly to the turbine. Therefore, a device called governor is used to measure and regulate the speed of the turbine runner.

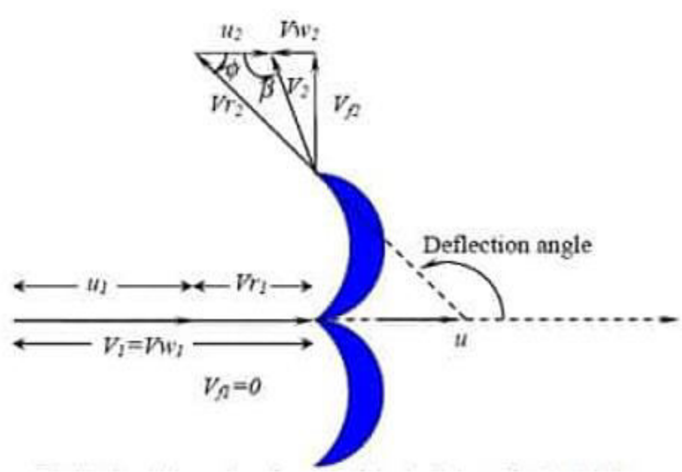
Working of Pelton wheel:

- The water stored at a high head is made to flow through the penstock and reaches the nozzle of the Pelton turbine.
- The nozzle increases the K.E. of the water and directs the water in the form of a jet.
- The jet of water from the nozzle strikes the buckets (vanes) of the runner. This made the runner to rotate at very high speed.
- The quantity of water striking the vanes or buckets is controlled by the needle valve present inside the nozzle.
- The generator is attached to the shaft of the runner which converts the mechanical energy of the runner into electrical energy.

Velocity Triangles Diagram For Pelton Wheel:

- The jet of water from the nozzle strikes the bucket at the splitter, which splits up the jet into two parts. These parts of the jet glides over the inner surfaces and comes out at the outer edge.
- The splitter is the inlet tip and the outer edge of the bucket is the outlet tip of the bucket.
- The inlet velocity triangle is drawn at the splitter and the outer velocity triangle is drawn at the outer edge of the bucket.





Where,

V_1= velocity of jet at inlet
u_1= velocity of the vane/bucket at inlet

V_{r1} = relative velocity of jet at inlet
α = angle between the direction of the jet and the direction of motion of the vane, guide blade angle (Here in this figure it is zero)
θ = angle made by v_{r1} with the direction of motion of vane at the inlet, vane angle at inlet (=0)
V_{w2} = velocity of whirl at outlet
V_{f2} = velocity of flow at the outlet
β = angle between v_2 with the direction of motion of vane at the outlet
φ = angle made by v_{r2} with the direction of motion of vane at the outlet, vane angle at outlet

Pelton Wheel – Efficiencies and Work done
(i) The work done by the jet on runner per second = **$\rho aV_1 (V_{w1} \pm V_{w2})$**

(ii) The work done per second per unit weight of water striking =**$1/g(V_{w1}+V_{w2})u$**

(iii) Hydraulic efficiency,

(iii) Hydraulic efficiency, $\eta_h = \dfrac{2(V_{w1} \pm V_{w2})u}{V_1^2}$

$$\eta_h = \frac{power\ developed\ by\ the\ runner}{power\ supplied\ at\ the\ inlet\ of\ turbine}$$

η_h is maximum when u = $\dfrac{V_1}{2}$, and

$(\eta_h)_{max} = \dfrac{1+\cos\phi}{2}$ Assuming No friction (i.e. K = 1)

(iv) Mechanical efficiency = shaft power / Bucket Power

(**v) Volumetric efficiency, =** Volume of water actually striking the runner / total water supplied by the jet to the turbine

(vi) Overall efficiency, = shaft power / water power = P/ ρgQH

Design Of Pelton Wheel :
1. Velocity of jet at inlet V1= Cv √2gH ……..

where Cv = coefficient of velocity = 0.98-0.99

2. Velocity of wheel where u = φ √2gH ………..Where φ is the speed ratio = 0.43-0.48

3. The angle of deflection is 165° unless mentioned.

4. Pitch or mean diameter D can be expressed by, u= πDN / 60

5. Jet ratio M =D/d (12 in most cases/calculate), d = nozzle diameter

6. Number of bucket on a runner Z = 15 + D/2d = 15 + 0·5 m

7. Number of Jets = obtained by dividing the total rate of flow through the turbine by the rate of flow through the single jet

8. Size of Bucket: Axial Width, radial length, depth

Advantages of Pelton turbine

- It has simple construction
- It is easy to maintain
- Intake and exhaust of water takes place at atmospheric pressure hence no draft tube is required
- No cavitation problem
- Its overall efficiency is high
- It can be both axial and radial flow
- It can work on low discharge

Disadvantages of Pelton turbine

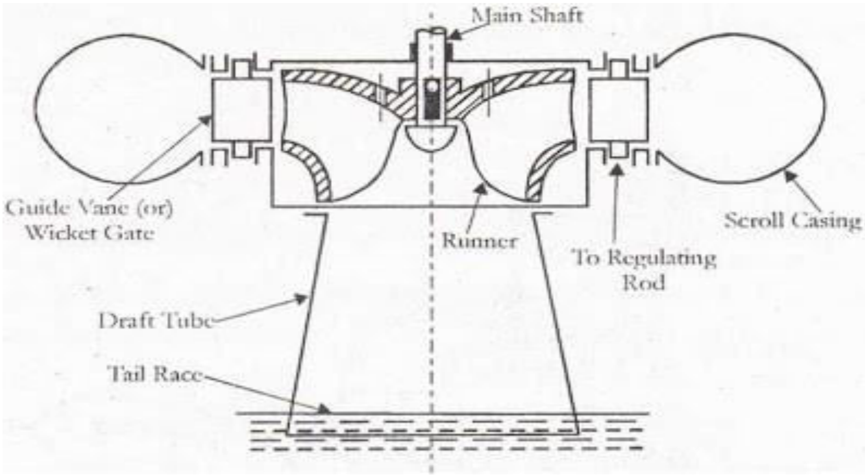
- It requires high head for operation
- Turbine size is generally large
- Its efficiency decreases quickly with time
- Due to high head, it is very difficult to control variations in operating head

Applications of Pelton Wheel :

1. Pelton wheels are the preferred turbine for hydro-power when the available water source has a relatively high hydraulic head at low flow rates.
2. Pelton wheels are made in all sizes. For maximum power and efficiency, the wheel and turbine system is designed such that the water jet velocity is twice the velocity of the rotating buckets.
3. There exist in multi-ton Pelton wheels mounted on vertical oil pad bearing in hydroelectric power.

FRANCIS TURBINE

Diagram Of Francis Turbine :



Parts Of Francis Turbine

Francis turbine consists mainly of the following parts

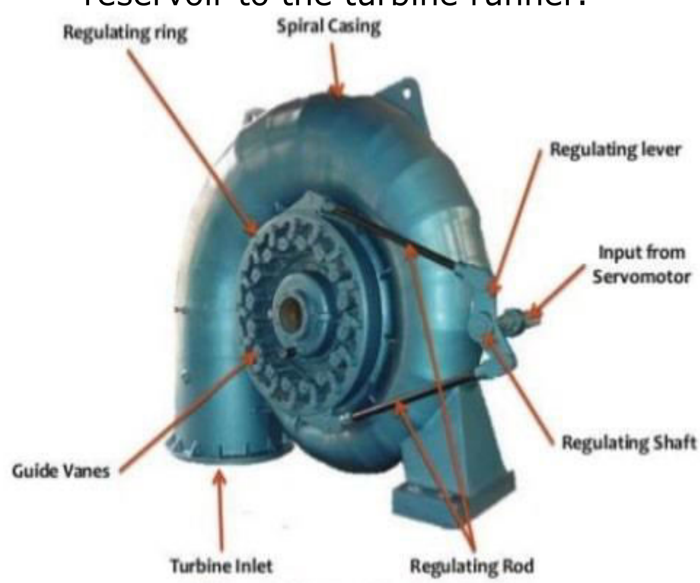
a) Spiral or scroll casing – It is a closed passage whose cross-sectional area gradually decreases along the flow direction. The area is maximum at the inlet and nearly zero at the outlet.

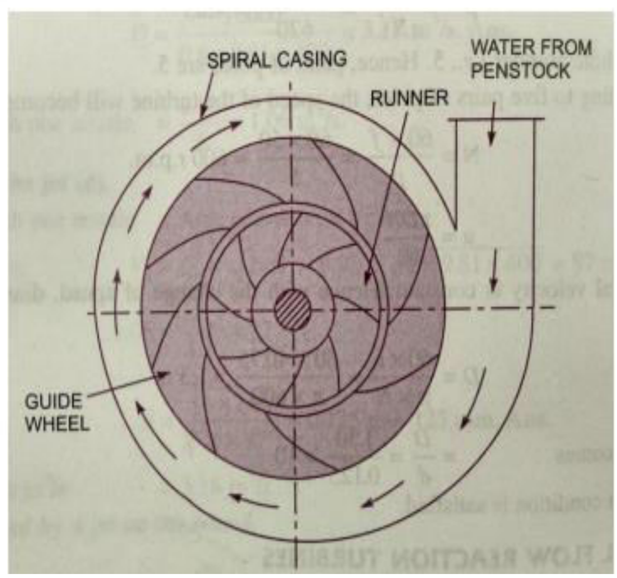
b) Guide mechanism – Guides vanes direct the water onto the runner at an angle appropriate to the design. The driving force on the runner is both due to impulse and reaction effects. The number if a runner blade usually varies between 16 and 24.

c) Runner and turbine main Shaft :

d) Draft tube: It is a gradually expanding tube which discharges the water passing through the runner to the tailrace.

e) Penstock: It is the large pipe which conveys water from the upstream of the reservoir to the turbine runner.





Spiral casing or scroll Casing :

- The casing of the Francis turbine is designed in a spiral form with a gradually increasing area.
- Most of these machines have vertical shafts although some smaller machines of this type have a horizontal shaft. The fluid enters from the penstock

(pipeline leading to the turbine from the reservoir at high altitude) to a spiral casing that surrounds the runner.

- This casing is known as scroll casing or volute. The cross-sectional area of this casing decreases uniformly along the circumference to keep the fluid velocity constant in magnitude along its path towards the stay vane. This is so because the rate of flow along the fluid path in the volute decreases due to continuous entry of the fluid to the runner through the openings of the stay vanes.
- The casing is made of a cast steel, plate steel, concrete, or concrete and steel depending upon the pressure to which it is subjected. Out of these a plate steel scroll casing is commonly provided for turbines operating under 30 m or higher heads.

The advantages of this design are

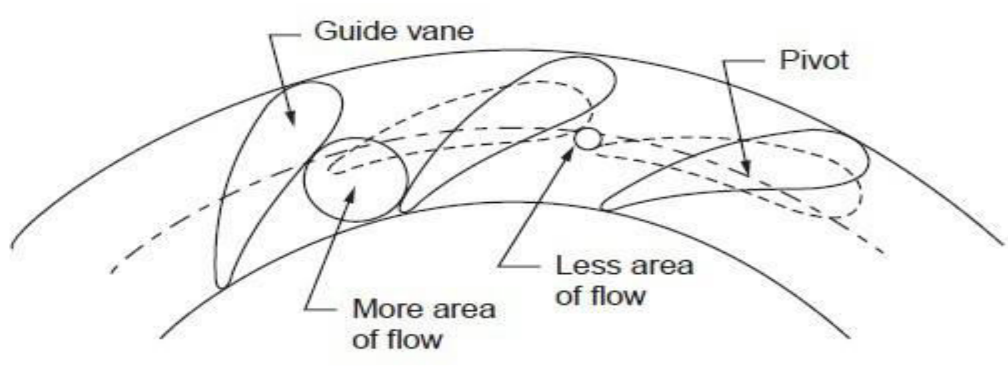
i) Smooth and even distribution of water around the runner.
ii) Loss of head due to the formation of eddies is avoided.
iii) The efficiency of the flow of water to the turbine is increased.
In big units stay vanes are provided which direct the water to the guide vanes.
The casing is also provided with inspection holes and a pressure gauge connection.

The selection of material for the casing depends upon the head of water to be supplied

For a head — up to 30 meters —concrete is used.
For a head — from 30 to 60 meters — welded rolled steel plates are used.
For a head of above 90 meters. — cast steel is used.

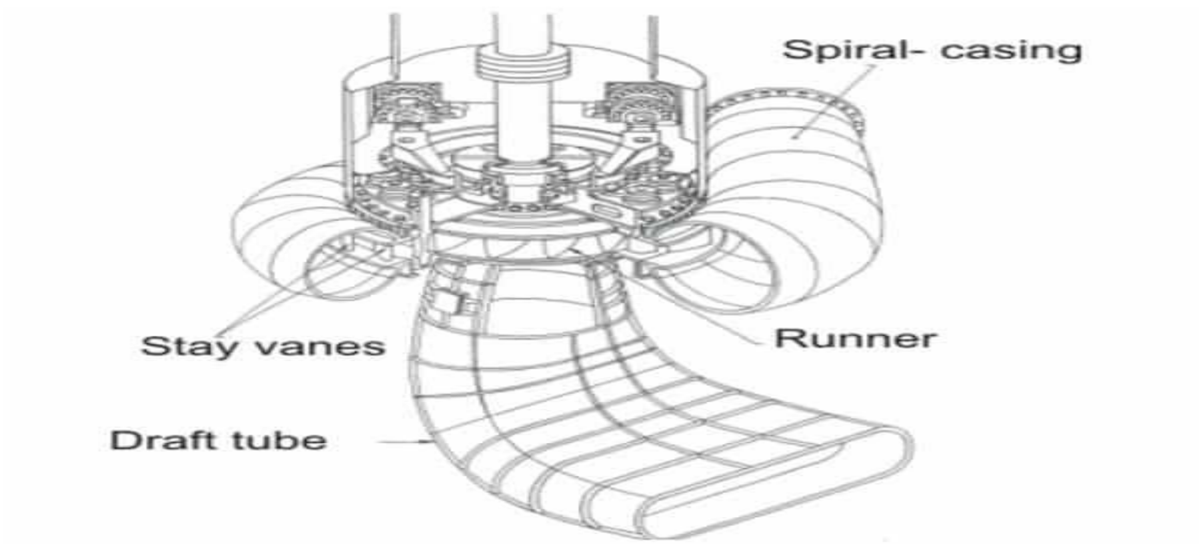
Guide Mechanism :

- It consists of a stationary circular wheel all around the runner of the turbine. The stationary guide vanes are fixed on the guide mechanism. The guide vanes allow the water to strike the vanes fixed on the runner without shock at the inlet.
- The guide vanes(also called as wicket gates) are fixed between two rings. This arrangement is in the form of a wheel and called a guide wheel. Each vane can be rotated about its pivot center.
- The opening between the vanes can be increased or decreased by adjusting the guide wheel. The guide wheel is adjusted by the regulating shaft which is operated by a governor.
- The **guide blades** rest on pivoted on a ring and can be rotated by the rotation of the ring, whose movement is controlled by the governor. In this way the area of blade passage is changed to vary the flow rate of water according to the load so that the speed can be maintained constant. The variation of area between guide blades is illustrated in Figure



Guide vanee and giude wheel

- The **guide mechanism** provides the required quantity of water to the runner depending upon the load conditions. The guide vanes are in general made of cast steel.



A Francis turbine

Runner and Turbine Main Shaft :

- Runner is a circular wheel on which a series of radial curved vanes are fixed. The surface of the vanes are made very smooth. The radial curved vans are so shaped that the water enters and leaves the runner without shocks.
- The flow in the runner of a modern Francis turbine is partly radial and partly axial.
- The runners may be classified as

  i) Slow ii) Medium iii) Fast

- The runner may be cast in one piece or made of separate steel plates welded together. The runner made of CI for small output, cast steel, or stainless steel or bronze for large output. The runner blades should be carefully finished with a high degree of accuracy.

- The runner may be keyed to the shaft which may be vertical or horizontal. The shaft is made of steel and is forged it is provided with a collar for transmitting the axial thrust.

Draft Tube :

- The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. The water at the exit cannot be directly discharged to the tailrace. A tube or pipe of the gradually increasing area is used for discharging water from the exit of the turbine to the tailrace. This tube of increasing area is called the draft tube
- The water after doing work on the runner passes on to the tall race through a tube called a draft tube.
- It is made of riveted steel plate or pipe or a concrete tunnel.
- The cross-section of the tube increases gradually towards the outlet. The draft tube connects the runner exit to the tailrace.
- This tube should be drowned approximately 1 meter below the tailrace water level.

Function of draft tube –

i) To decrease the pressure at the runner exit to a value less than atmospheric pressure and thereby increase the effective working head.
ii) To recover a part of electric energy into pressure head at the exit of the draft tube. This enables easy discharge to the atmosphere.

Types of Draft Tube:

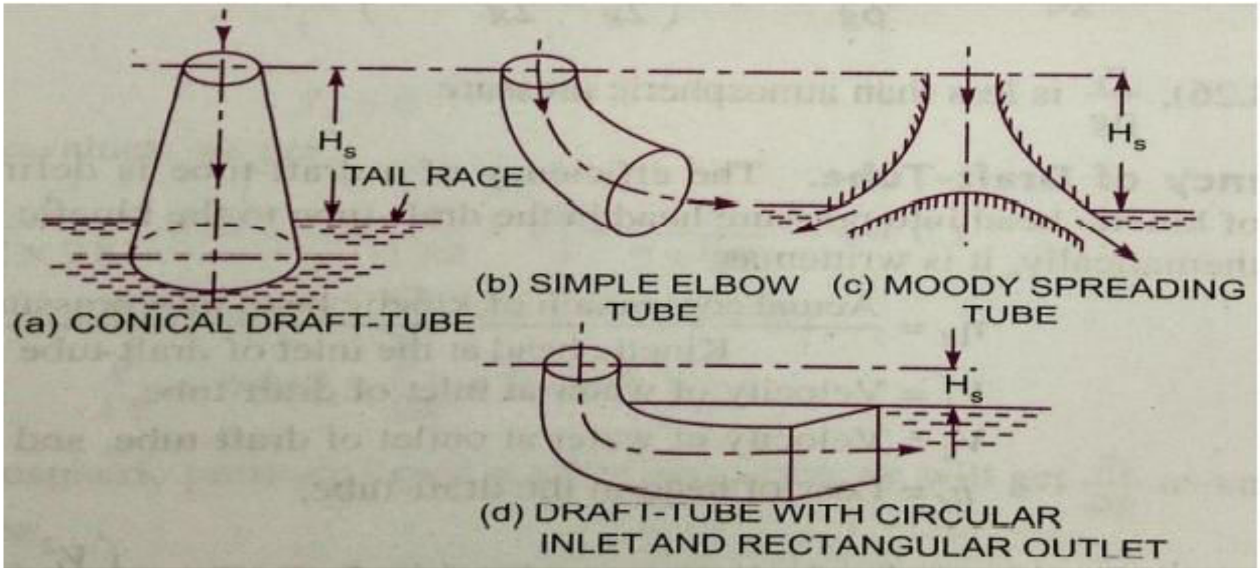
i. Conical draft tube
ii. Simple elbow draft tube
iii. Moody spreading draft tube
iv. Elbow draft tube with circular cross-section at inlet and rectangular at outlet

(1) Conical Draft Tubes— This is known as a tapered draft tube and used in all reaction turbines where conditions permit. It is preferred for low specific speed and Francis turbine. The maximum cone angle is 8° (a = 40°). The hydraulic efficiency is 90%.

(2) Simple Elbow Tubes-The elbow type draft tube is often preferred in most of the power plants. If the tube is large in diameter; ‘it may be necessary to make the horizontal portion of some other section. A common form of section used is over or rectangular. It has low efficiency of around 60%.

(3) Moody Spreading Tubes- This tube is used to reduce the whirling action of discharge water when the turbine runs at high speed under low head conditions. The draft tube has an efficiency of around 85%.

(4) Elbow with circular inlet and rectangular outlet— This tube has circular cross-section at the inlet and rectangular section at the outlet. The change from the circular section to the rectangular section takes place in the bend from the vertical leg to the horizontal leg. The efficiency is about 85%.



Types Of Francis Turbines :

There are mainly two types of Francis turbines known as open flume type and closed type.

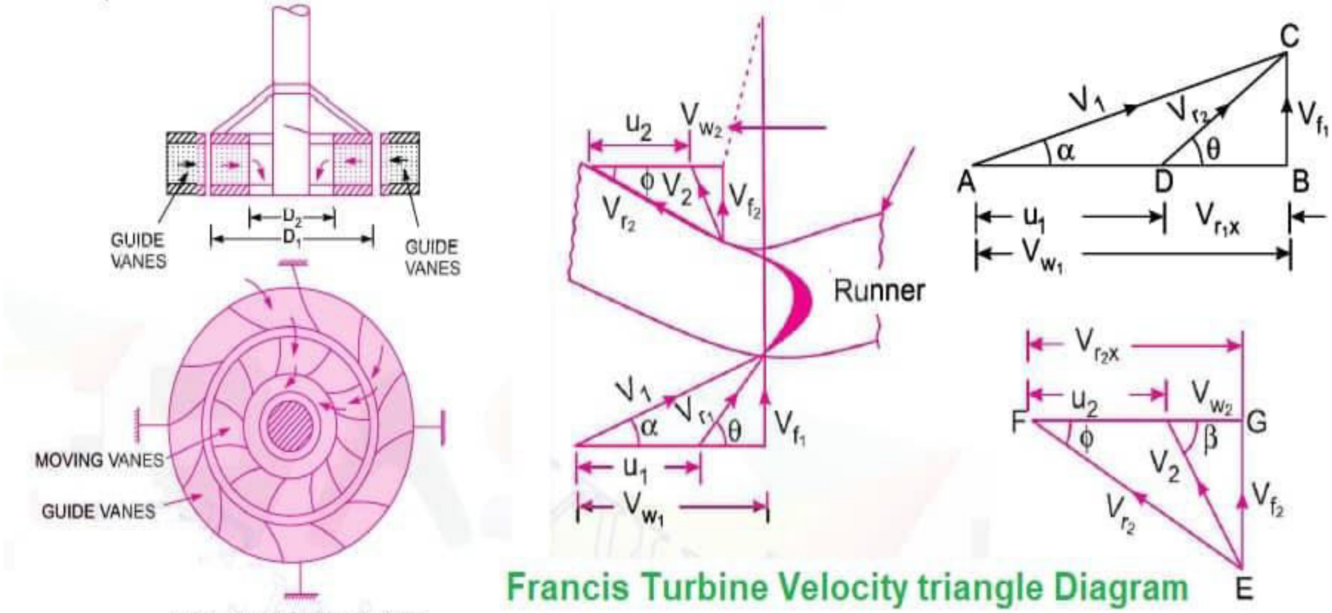
- In **open flume type**, the turbine is immersed underwater of the headrace in a concrete chamber and discharges into the tailrace through the draft tube. The main disadvantage of this type is that runner and the guide-vane mechanism is under the water and they are not open either for inspection or repair without draining the chamber.
- In the **closed type,** the water is led to the turbine through the penstock whose end is connected to the spiral casing of the turbine. The open flume type is used for the plants of 10 meters head whereas, closed type is preferred above 30 meters head. The guide vanes are provided around the runner to regulate the water flowing through the turbine The guide vanes provide gradually decreasing area of
flow for all gate openings, so that no eddies are formed, and efficiency does not suffer much even at part load conditions.

Working principles of Francis turbine

- The water is admitted to the runner through guide vanes or wicket gates. The opening between the vanes can be adjusted to vary the quantity of water admitted to the turbine. This is done to suit the load conditions.
- The water enters the runner with a low velocity but with a considerable pressure. As the water flows over the vanes the pressure head is gradually converted into velocity head.

- This kinetic energy is utilized in rotating the wheel Thus the hydraulic energy is converted into mechanical energy.
- The outgoing water enters the tailrace after passing through the draft tube. The draft tube enlarges gradually and the enlarged end is submerged deeply in the tailrace water.
- Due to this arrangement a suction head is created at the exit of the runner.

Francis Turbine Velocity triangle Diagram :



Inward radial flow turbine.

The majority of the Francis turbines are **inward radial flow type** and most preferred for medium heads. The inward flow turbine has many advantages over the outward flow turbine as listed below :

1. The chances of eddy formation and pressure loss are reduced as the area of flow becomes gradually convergent.

2. The runaway speed of the turbine is automatically checked as the centrifugal force acts outwards while the flow is inward.

3. The guide vanes can be located on the outer periphery of the runner, therefore, better regulation is possible.

4. The frictional losses are less as the water velocity over the vanes is reduced.

5. The inward flow turbine can be used for fairly high heads without increasing the speed of the turbine as the centrifugal head supports a considerable part of the supply head.

In Inward radial Flow turbine Velocity triangle Diagram
where,

V_{w1} = Velocity of whirl at inlet

V_{w2} = Velocity of whirl at outlet

u_1= Tangential velocity of whirl at inlet

u_2= Tangential velocity of whirl at outlet

V_{f1} = Velocity of flow at inlet

V_{f2} = Velocity of flow at Outlet

V_1 = Absolute velocity of water at the inlet of the runner

V_2 = Absolute velocity of water at the Outlet of the runner

V_{r1} = Relative Velocity at Inlet of the runner

V_{r2} = Relative Velocity at the outlet of the runner

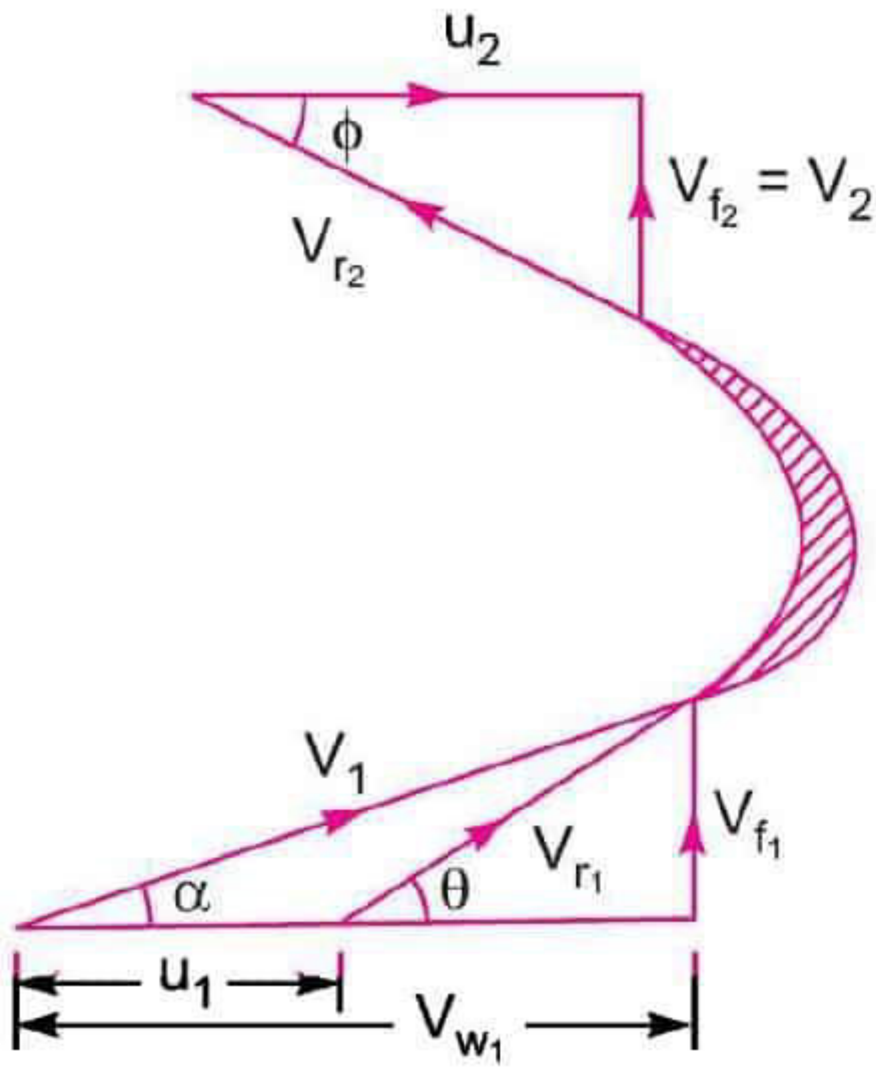
Φ = Vane angle at the exit.

θ = Vane angle at inlet

α = Guide vane angle

The velocity triangle at inlet and outlet of the Francis turbine is drawn in the same way as in case of inward flow creation turbine . as in case of Francis turbine, the discharge is radial at the outlet, the velocity of whirl at the outlet (i.e. V_{w2}) will be zero. Hence velocity diagram for Francis turbine is shown below

We Know, absolute velocity at the outlet is 90° i.e. β= 90°



Velocity triangle

Diagram for Francis turbine

Flow ratio, Kf = Vf1 / √2gH

Flow ratio varies from 0.15 to 0.30

Speed ratio, Ku= u1 / √2gH

Speed ratio varies between 0.6 to 0.9

The ratio of width (B1) to the diameter of the wheel (D1), n= B1/D1

n ratio varies from 0.1 to 0.45

Specific speed (Ns): of a turbine is defined as the speed of a geometrically turbine which would develop unit power when working under a unit head.

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

equation of specific speed of the turbine

Where P = shaft power, and H = net head on the turbine

Specific speed plays an important role in the selection of the type of turbine. Or, The suitability of a turbine for a particular depends on (a) head of water (b) rotational speed (c) power developed, which together fix a parameter called 'specific speed'.

Cavitation:

The formation, growth, and collapse of vapor filled cavities or a bubble in a flowing liquid due to local fall in fluid pressure is called cavitation. The critical value of cavitation factor (σc) is given by

$$\sigma c = (Ha - Hv - Hs) / H$$

Where,

Ha = atmospheric pressure head in meters of water,

Hv = vapour pressure in meters of water corresponding to the water temperature.

H = working head of turbine (difference between head race and tail race levels in meters)

Hs = suction pressure head (or height of turbine inlet above tail race level) in meters.

The value of critical factor depends upon specific speed of the turbine.

If the value of σ is greater than σc then cavitation will not occurred in the turbine or pump.

Effect of cavitation:

(i) Roughening of the surface by pitting

(ii) Increase vibration due to irregular collapse of cavities.

(iii) The actual volume of liquid flowing through the machine is reduced.

(iv) Reduce output power

(v) Reduce efficiency

Method to avoid cavitation:

(i) Runner/turbine may be kept underwater

(ii) Design cavitation free runner

(iii) Selecting proper material, use stainless steel, alloy steel

(iv) Blades coated with harder material

(v) Selecting a runner of a proper specific speed

Efficiencies Of Francis Turbines :

1. Hydraulic efficiency :

It is defined as the ratio of the power produced by the turbine runner and the power supplied by the water at the turbine inlet.

2. Volumetric efficiency :

- It is possible some water flows out through the clearance between the runner and casing without passing through the runner.
- Volumetric efficiency is defined as the ratio between the volume of water flowing through the runner and the total volume of water supplied to the turbine.

3. Mechanical efficiency :

The power produced by the runner is always greater than the power available at the turbine shaft. This is due to mechanical losses at the bearings, windage losses and other frictional losses.

4. Overall efficiency :

This is the ratio of power output at the shaft and power input by the water at the turbine inlet.

Advantage of Francis Turbine :

1. The difference in the operating head can be extra simply controlled in Francis turbine than in the Pelton wheel turbine.
2. The ratio of utmost and least operating head can even be two in the case of Francis Turbine.
3. The mechanical efficiency of the Pelton wheel decreases faster by wear than Francis turbine.
4. Francis turbine variation in operating head can be more simply controlled.
5. No head failure occurs still at the low discharge of water.
6. The size of the runner and generator is small.
7. Small changes in efficiency over time.
8. Operating head can be utilized even when the variation in tailwater level is relatively large when compared to the total head.

Disadvantage of Francis Turbine :

1. The water which is not dirt-free can cause extremely rapid wear in high head Francis turbine.
2. As spiral casing is stranded, the runner is not simply available. Therefore dismantle is hard.
3. The repair and inspection is much harder reasonably.
4. Cavitation is an ever-present hazard.
5. Current losses are certain
6. Head 50 percent lower can be a harmful effect on the efficiency as well as cavitation danger becomes more serious.

Application of Francis Turbine :

- Electricity production can be estimated with the help of flow rate and head.
- Francis turbine may be designed for a wide range of head and flow.
- It has high efficiency.

- They may be used as Pump.

AXIAL FLOW REACTION TURBINE:

If the water flows parallel to the axis of the rotation shaft the turbine is known as axial flow turbine.

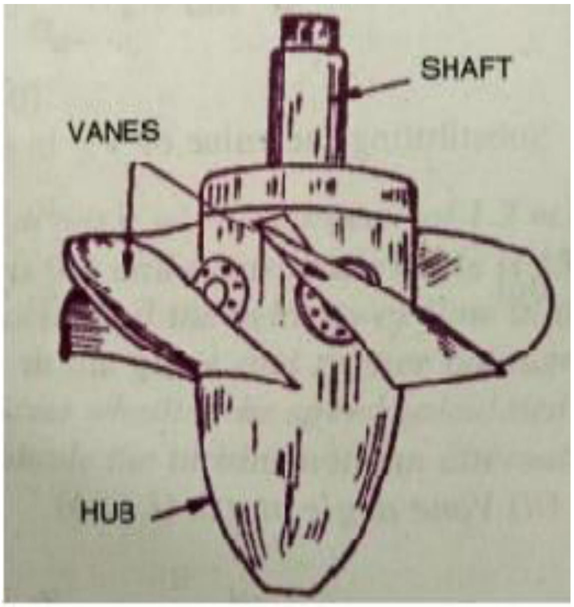
If the head at inlet of the turbine is the sum of pressure energy and kinetic energy and during the flow of the water through the runner a part of pressure energy in converted in to kinetic energy, the turbine is known as reaction turbine.

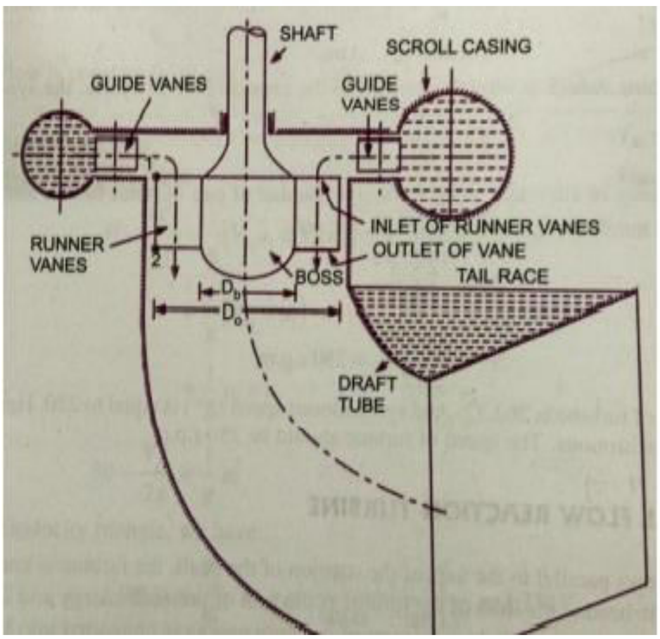
For axial flow reaction turbine, the shaft of the turbine is vertical. The lower end of the shaft is made longer known as “hub” or “boss”. The vanes are fixed on the hub and acts as a runner for the axial flow reaction turbine.

The important types of axial flow reaction turbines are:

- Propeller Turbine
- Kaplan Turbine

When the vanes are fixed to the hub and they are not adjustable the turbine is known as propeller turbine. But if the vanes on the hub are adjustable, the turbine is known as Kaplan turbine. This turbine is suitable, where large quantity of water at low heads is available.





The main parts of the Kaplan turbine are:

- Scroll casing
- Guide vanes mechanism
- Hub with vanes or runner of the turbine
- Draft tube

Between the guide vanes and the runner the water in the Kaplan turbine turns through a right angle in to the axial angle direction and then posses through the runner. The runner of the Kaplan turbine has four or six or eight in some cases blades and it closely resembles a ships propeller. The blades (vanes) attached to a hub or bosses are so shaped that water flows axially through the runner.

The runner blades of a propeller turbine are fixed but the Kaplan turbine runner heads can be turned about their own axis, so that their angle of inclination may be adjusted while the turbine is in motion. The adjustment of the runner blades in usually carried out automatically by means of a servomotor operating inside the hollow coupling of turbine and generator shaft.

When both guide vane angle and runner blade angle may thus be varied a high efficiency can be maintained over a wide range of operating conditions. i.e. even at part load, when a lower discharge is following through the runner a high efficiency can be attained in case of Kaplan turbine.

The flow through turbine runner does not affect the shape of velocity triangles as blade angles are simultaneously adjusted, the water under all the working conditions flows through the runner blades without shock. The eddy losses which are inevitable in Francis and propeller turbines are completely eliminated in a Kaplan Turbine.

Working Proportions of Kaplan Turbine:

The main dimensions of Kaplan Turbine runners are similar to Francis turbine runner. However the following are main deviations,

Choose an appropriate value of the ratio , where d in hub or boss diameter and D is runner outside diameter.

The value of n varies from 0.35 to 0.6 The discharge Q flowing through the runner is given by

$$\mathbf{Q = \frac{\pi}{4} (D^2 - d^2) V_f} \qquad \text{Where, } \mathbf{V_f = k_f} \sqrt{2gH}$$

The value of flow ratio $\mathbf{k_f}$ for a Kaplan turbine is 0.7

The runner blades of the Kaplan turbine are twisted, the blade angle being greater at the outer tip than at the hub. This is because the peripheral velocity of the blades being directly proportional to radius. It will valy from section to section along the blade, and hence in order to have shock free entry and exit of water over the blades with angles varying from section to section will have to be designed.

Difference Between Impulse and Reaction Turbine

S.no	Impulse Turbine	Reaction Turbine
1.	In an impulse turbine, the steam flows through the nozzle and strike on the moving blades.	In the reaction turbine, first, the steam flows through the guide mechanism and then flows through the moving blades.
2.	Steam strikes on the buckets with kinetic energy.	The steam glides over the moving blades with both pressure and kinetic energy.
3.	During the flow of steam through moving blades, its pressure remains constant.	During the flow of steam through moving blades its pressure reduces.
4.	The steam may or may not be admitted to the whole circumference.	The steam must be admitted over the whole circumference.
5.	The blades of impulse turbine are symmetrical.	The blades of reaction turbine are not symmetrical.
6.	While gliding over the blades the relative velocity of steam remains constant.	In reaction turbine, while gliding over the blades the relative velocity of steam increases.
7.	For the same power developed, the number of stages required is less.	For the same power developed, the number of stages required is more.
8.	The direction of steam flow is radial to the direction of turbine wheel.	The direction of steam flow is radial and axial to the turbine wheel.
9.	It requires less maintenance work.	It requires more maintenance work.
10.	It is suitable for low discharge.	It is suitable for medium and high discharge.
11.	Pelton Wheel is the example of impulse turbine.	Francis turbine, Kaplan turbine etc. are the examples of reaction turbine.

DIFFERENCE BETWEEN FRANCIS TURBINE & KAPLAN TURBINE

FRANCIS TURBINE	KAPLAN TURBINE
Radially inward or mixed flow turbine	Axial flow turbine
Medium head turbine (60m to 250m)	Low head turbine(up to 30m)
Medium specific speed (50 to 260)	High specific speed (260 to 1000)
Horizontal or vertical disposition of shaft	Only vertical disposition of shaft
Runner vanes are not adjustable	Runner vanes are adjustable
Large number of runner vanes (16 to 24 vanes)	Small number of runner vanes (3 to 8), usually 4
Ordinary governor is sufficient	Heavy duty governor is quite essential
Centripetal type	Propeller type

CENTRIFUGAL PUMP

Introduction:

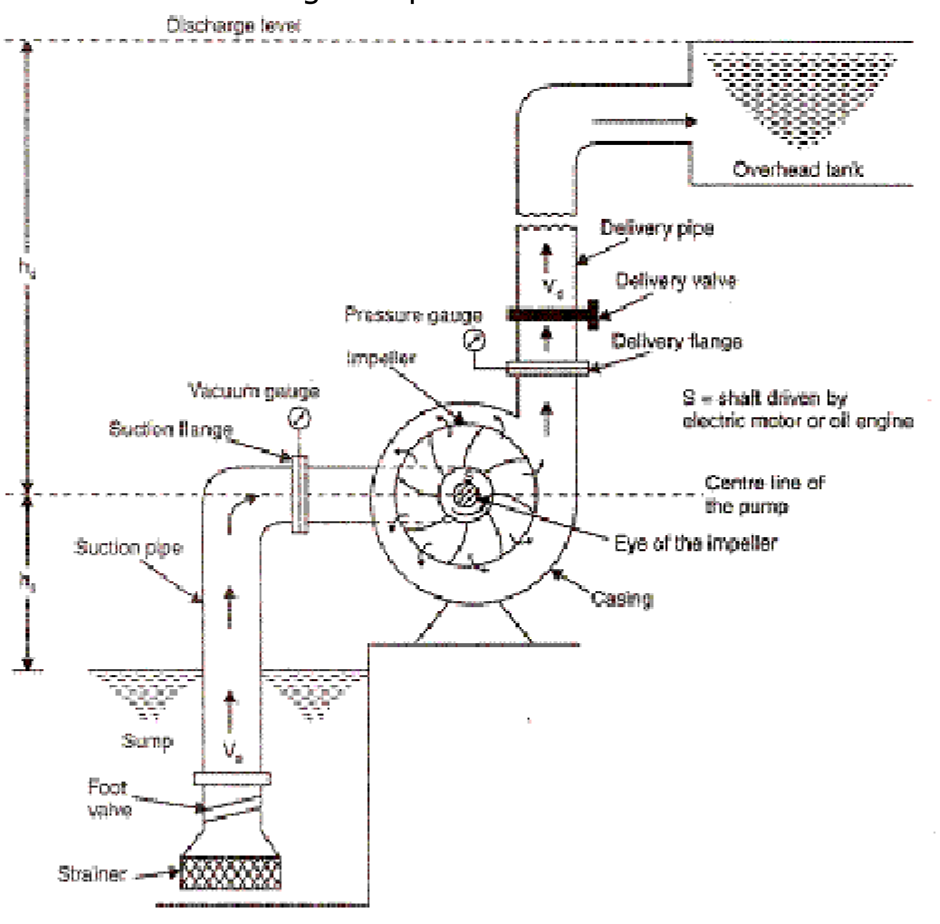
Centrifugal pumps are the most widely used of all the turbo machine (or rotodynamic) pumps. This type of pumps uses the centrifugal force created by an impeller which spins at high speed inside the pump casing.

Principle: Its principle work on Centrifugal force.

CONSTRUCTION DETAILS OF A CENTRIFUGAL PUMP:

Components of Centrifugal pump is classified as the following :

1. Stationary components
2. Rotating components



1. Stationary components of the centrifugal pump are the following:

a) Casing: – It is an air tight passage surrounding the impeller. It is designed in such a way that the kinetic energy of the water discharged at the outlet of the impeller is converted into pressure energy before the water leaves the casing and enters the delivery pipe.

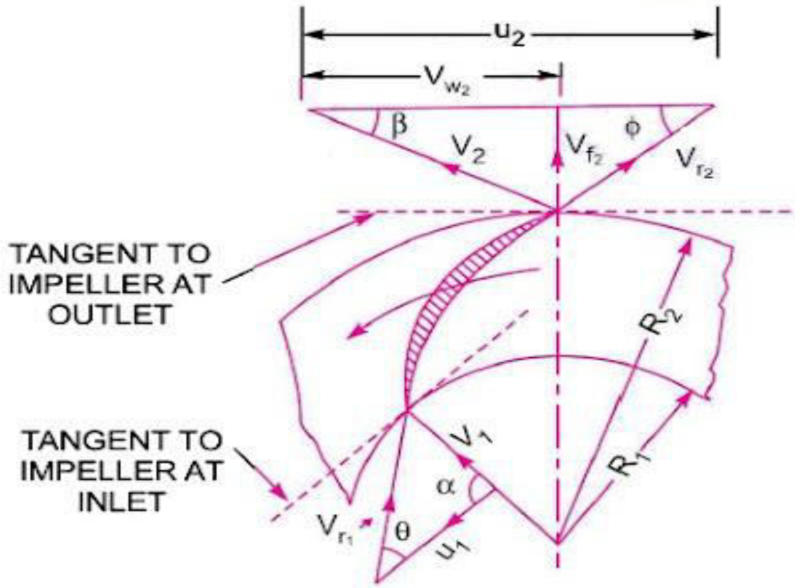
Types of Centrifugal pump casing:-

1) Volute casing: – It is spiral type of casing in which area of flow increase gradually. The increase in area of flow decreases the velocity of flow and increases the pressure of water.
2) Vortex casing: – if a circular chamber is introduced between casing and the impeller, the casing is known as vortex casing.
3) Casing with guide blades: – the impeller is surrounded by a series of guide blades mounted on a ring know as diffuser.
b) Suction pipe: –
The pipe whose one ends is connected to the inlet of the pump and other end dip into water in a sump.
c) Delivery pipe: – The pipe whose one end is connected to the outlet of the pump and other end is involved in delivering the water at a required height.
2. Rotating component of the centrifugal pump is Impeller.
Impeller: – It is the main rotating part that provides the centrifugal acceleration to the fluid. Classification of impeller:
a) Based on direction of flow:
1) Axial-flow: – the fluid maintains significant axial-flow direction components from the inlet to outlet of the rotor.
2) Radial-flow: – the flow across the blades involves a substantial radial-flow component at the rotor inlet, outlet and both.
3) Mixed-flow: – there may be significant axial and radial flow velocity components for the flow through the rotor row.
b) Based on suction type:
1) Single suction: – liquid inlet on one side.
2) Double suction: – liquid inlet to the impeller symmetrically from both sides.
c) Based on mechanical construction:
1) Closed: – shrouds or sidewall is enclosing the vanes.
2) Open: – no shrouds or wall to enclose the vanes.
3) Semi–open or vortex type.
Working Of Centrifugal Pump:
Water is drawn into the pump from the source of supply through a short length of pipe (suction pipe). Impeller rotates; it spins the liquid sitting in the cavities between the vanes outwards and provides centrifugal acceleration with the kinetic energy.
This kinetic energy of a liquid coming out an impeller is harnessed by creating a resistance to flow. The first resistance is created by the pump volute (casing) that catches the liquid and shows it down.
In the discharge nozzle, the liquid further decelerates and its velocity is converted to pressure according to BERNOULLI'S PRINCIPAL.

Work done by the centrifugal pump on water

In case of centrifugal pump, work will be done by the impeller on the water. Expression for the work done by the impeller on the water will be determined by drawing the velocity triangles at inlet and outlet of the impeller.

Let us see here a typical section of a centrifugal pump that indicates the impeller blade as displayed here in following figure. We are interested here to find out the work done by the centrifugal pump on the water. Energy interaction will take place only in the rotor i.e. impeller of the centrifugal pump.



Velocity triangles will be drawn at the inlet and outlet tips of the vanes fixed to an impeller.

For best efficiency of the pump, water need to enter the impeller radially at inlet. Therefore, absolute velocity of water at inlet will make an angle of 90 degree with the direction of motion of the impeller at inlet.

As we have discussed above that absolute velocity of water at inlet will make an angle of 90 degree with the direction of motion of the impeller at inlet, therefore angle α = 0 and velocity of whirl at inlet $V_{w1} = 0$.

Let us assume the following data as mentioned here.

N = Speed of the impeller in R.P.M

D_1 = Diameter of the impeller at inlet

u_1 =Tangential Velocity of impeller at inlet

V_1 = Absolute velocity of water at inlet

V_{r1} = Relative velocity of water at inlet

α = Angle made by absolute velocity of water at inlet with the direction of motion of vane

θ = Angle made by relative velocity of water at inlet with the direction of motion of vane

D_2 = Diameter of the impeller at outlet

u_2 =Tangential Velocity of impeller at outlet

V_2 = Absolute velocity of water at outlet

V_{r2} = Relative velocity of water at outlet

β = Angle made by absolute velocity of water at outlet with the direction of motion of vane

φ = Angle made by relative velocity of water at outlet with the direction of motion of vane

Tangential velocity of water at inlet, $u_1 = \pi D_1 N/60$

Tangential velocity of water at outlet, $u_2 = \pi D_2 N/60$

As we know that in case of radially inward flow reaction turbine, the work done by the water on the runner per second per unit weight of the water striking per second will be given by following equation as mentioned here.

Work done by the water on the runner per second per unit weight of the water striking per second = $(1/g) \times [V_{w1} u_1 - V_{w2} u_2]$

As we know that a centrifugal pump is the reverse of a radially inward flow reaction turbine, therefore work done by the impeller on the water in case of a centrifugal pump will be given by following equation as mentioned here.

Work done by the impeller on the water per second per unit weight of the water striking per second = - (work done in case of turbine)

Work done by the impeller on the water per second per unit weight of the water striking per second = $(1/g) \times [V_{w2} u_2 - V_{w1} u_1]$

Work done by the impeller on the water per second per unit weight of the water striking per second = $(1/g) \times V_{w2} u_2$

Because, absolute velocity of water at inlet will make an angle of 90 degree with the direction of motion of the impeller at inlet, therefore angle $\alpha = 0$ and $V_{w1} = 0$.

Above equation also provides the head imparted to the water by the impeller or energy given by impeller to the water per unit weight per second.

Work done by the impeller on water per second = $(W/g) \times V_{w2} u_2$

Where, W = Weight of water
$W = \rho \times g \times Q$
Where, Q = Flow rate of water
Q = Area x Velocity of flow
$Q = \pi \times D_1 \times B_1 \times V_{f1} = \pi \times D_2 \times B_2 \times V_{f2}$
Where, B_1 and B_2 are the width of impeller and V_{f1} and V_{f2} are the velocities of flow at the inlet and outlet.

Therefore, we have seen here two very important terms i.e. work done by the centrifugal pump on water and head imparted to the water by the impeller or energy given by impeller to the water per unit weight per second.

Work done by the impeller on water per second = $(W/g) \times V_{w2} u_2$

Head imparted to the water by the impeller or energy given by impeller to the water per unit weight per second = $(1/g) \times V_{w2} u_2$

HEADS AND EFFICIENCIES OF A CENTRIFUGAL PUMP

Suction Head (h_s)

Suction head is basically defined as the vertical distance between the centre line of centrifugal pump and the free surface of liquid (e.g. water) in the tank from which liquid is to be lifted. This vertical distance is also termed as suction lift.

The tank from which liquid need to be lifted will be termed as sump. Suction head or suction lift will be displayed by the symbol h_s as displayed here in following figure.

Delivery Head (h_d)

Delivery head is basically defined as the vertical distance between the centre line of centrifugal pump and the free surface of water in the tank to which water need to be delivered. Delivery head will be displayed by the symbol h_d as displayed here in following figure.

Static head (H_S)

Static head is basically defined as the sum of suction head and delivery head and it will be displayed by the symbol H_S. Mathematically we will write the expression for static head as mentioned here.

$$\mathbf{H_S = h_s + h_d}$$

Manometric head (H_m)

The manometric head is basically defined as the head against which a centrifugal pump has to do the work. Manometric head will be displayed by H_m.

Manometric head = Head imparted by the impeller to the water – loss of head inside the pump

Manometric head = $(V_{w2}\, u_2)/g$ - loss of head inside the pump

If there is no loss of head inside the pump, we will have following expression for manometric head as mentioned here.

$$\textbf{Manometric head} = (V_{w2}\, u_2)/g$$

Where, V_{w2} = Velocity of whirl at outlet
u_2 = Tangential velocity of impeller at outlet
g = Acceleration due to gravity

Manometric head could be expressed by the following expression also as mentioned here

Manometric Head = Total head at outlet of the pump – total head at the inlet of pump

$$H_m = [(P_O/\rho g) + (V_O^2/2g) + Z_O] - [(P_i/\rho g) + (V_i^2/2g) + Z_i]$$

Where,

$P_O/\rho g$ = Pressure head at the outlet of the pump i.e. h_d

$V_O^2/2g$ = Velocity head at the outlet of the pump i.e. $V_d^2/2g$

Z_O = Vertical height of the outlet of the centrifugal pump from datum line i.e. Z_d

$P_i/\rho g$ = Pressure head at the inlet of the pump i.e. h_s

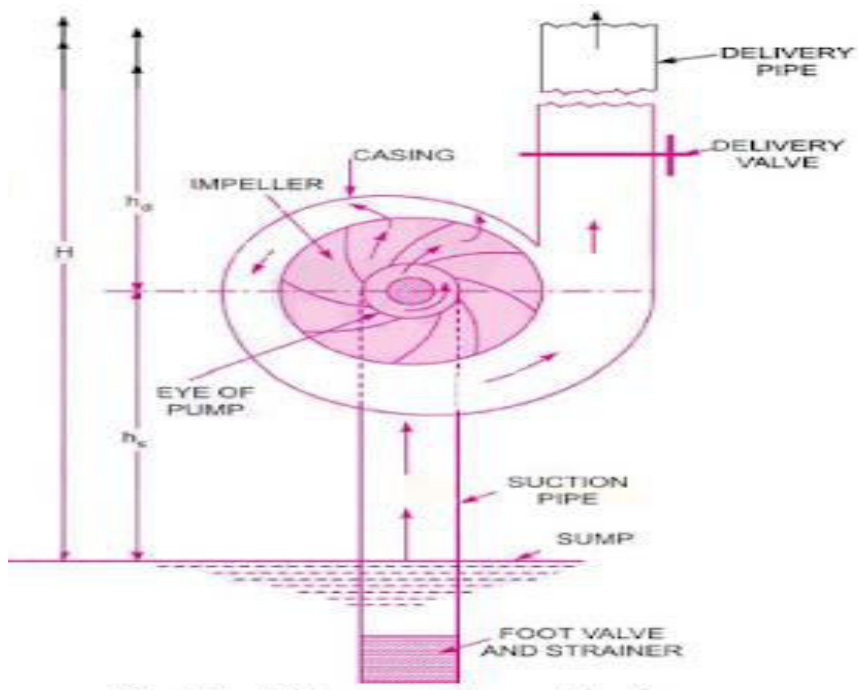
$V_i^2/2g$ = Velocity head at the inlet of the pump i.e. $V_s^2/2g$

Z_i = Vertical height of the inlet of the centrifugal pump from datum line i.e. Z_s

Manometric head could be expressed by the following expression also as mentioned here

Manometric head = Suction head + Delivery Head + Frictional head loss in suction pipe + Frictional head loss in discharge pipe + Velocity head in delivery or discharge pipe

$$\textbf{Manometric head} = h_s + h_d + h_{fs} + h_{fd} + V_d^2/2g$$



Efficiencies of a centrifugal pump

Let us first understand that how power will be transmitted from electrical motor to centrifugal pump. Power will be transmitted from electrical motor shaft to shaft of the centrifugal pump. Further power will be transferred from shaft of the centrifugal pump to impeller of the centrifugal pump. Further, power will be transferred from pump impeller to the water.

Therefore, if we think the power transmission here, we will easily conclude that there will be some losses of power when power will be transmitted between pump shaft to pump impeller and further between pump impeller to the water.

There will be following efficiencies related with centrifugal pump that we will discuss here.

1. Manometric Efficiency, η_{man}
2. Mechanical Efficiency, η_m
3. Overall efficiency, η_o

Manometric Efficiency, η_{man}

Manometric head is basically defined as the ratio of manometric head to the head imparted by centrifugal pump impeller to the water.

Mathematically manometric efficiency will be written by the following equation as mentioned here.

Manometric efficiency, η_{man} = Manometric Head / Head imparted by centrifugal pump impeller to the water

The power at the impeller of the pump will be more than the power given to the water at outlet of the pump. Manometric efficiency will also be defined as the power given to the water at outlet of the pump to the power available at the impeller of the pump.

Manometric efficiency, η_{man} = Power given to the water at outlet of the pump / Power available at the impeller of the pump

$$\eta_{man} = \frac{g \times H_m}{V_{w_2} \times u_2}$$

Mechanical efficiency

Power at the shaft of the centrifugal pump will be more than the power available at the pump impeller.

Mechanical efficiency will be defined as the ratio of power available at the pump impeller to the power available at the shaft of the centrifugal pump.

Mechanical efficiency, η_{mech} = Power available at the impeller of the pump/ Power available at the shaft of the centrifugal pump

$$\eta_m = \frac{\frac{W}{g}\left(\frac{V_{w_2} u_2}{1000}\right)}{\text{S.P.}}$$

Overall efficiency

Overall efficiency will be defined as the ratio of power output of the pump to the power input to the pump.

Power output of the pump in KW = Weight of water lifted (W) x H_m /1000

Power input to the pump = Power supplied by the electric motor = S.P.

$$\eta_o = \frac{\left(\frac{WH_m}{1000}\right)}{\text{S.P.}}$$

$$\eta_o = \eta_{man} \times \eta_m.$$

Priming of Centrifugal Pumps

Priming is the crucial step in the initiation of the centrifugal pump. These pumps are not capable of pumping gases (e.g., air). Priming is needed where the impeller is immersed in the liquid and no air exists inside. Thus, for an initial start-up, priming is an essential action. The other reason that shows the importance of priming is the fill-up of liquid in the casing, which intends to decrease the clearance capacity. There are different ways of priming a centrifugal pump, including manual, using a separator, vacuum pump, and jet pump.

Advantages of centrifugal pump

1. High flow discharge

Centrifugal pump is create **high** flow discharge so centrifugal pump is used for **high** flow process.

2. Low price

In centrifugal pump **low** numbers of components used so initial cost of centrifugal pump is low than reciprocating pump.

3. Continuous supply

Centrifugal pump is continuous supply of water so no Air vessel is required in centrifugal pump for continuous supply.

4. Low weight

In centrifugal pump number of parts is less than reciprocating pump so weight of centrifugal pump is also **low** than reciprocating pump.

5. Low wear and tear

In centrifugal pump no friction and tear produce during operation time, so wear and tear problem is less in centrifugal pump.

6. Used for air also

Centrifugal pump is compress of air also this most efficient advantages of centrifugal pump.

7. Low maintenance cost

In centrifugal pump friction is less so component is more failure in reciprocating pump so large maintenance cost required.

8. Uniform torque

Centrifugal pump is run at not uniform torque so centrifugal pump delivery fluid is uniform .

9. No air vessel required
Centrifugal pump is continuous supply of water so **no** Air vessel is required in centrifugal pump for continuous supply.

10. High life - In centrifugal pump no friction and tear produce during operation time, so wear and tear problem is less in centrifugal pump so **high** life of centrifugal pump then reciprocating pump

Disadvantages of centrifugal pump

1. Less pressure
Centrifugal pump is create **low** pressure than reciprocating pump. Reciprocating pump is suitable when high pressure water is required

2. Difficult operation
In centrifugal pump more mechanical components used than reciprocating pump. Centrifugal pump operation is difficult than reciprocating pump.

3. priming required
In centrifugal pump starting time priming is **required** but in reciprocating pump Self priming system so no priming is required.

4. Low deliveries head
Centrifugal pump is suitable for low delivery head but reciprocating pump is create high delivery head.

5. Low efficiency

Hydraulic efficiency of Centrifugal pump is **lower** than reciprocating pump.

Cavitation in centrifugal pump

In case of centrifugal pumps, Cavitation will occur at the inlet of the impeller of the pump or at the suction side of the pumps. Pressure at the suction side of the pump will be reduced considerably and hence chances of cavitation will be high at the suction side of the centrifugal pump.

Now, let us think the case in which cavitation will occur in centrifugal pump.

Cavitation will occur, if the pressure at the suction side of the centrifugal pump will be dropped below than the vapour pressure of liquid flowing through pump.

We can come to know about cavitation in centrifugal pump by observing the efficiency of pump and head developed by the pump. If there is sudden drop in the efficiency and head developed by the pump, it indicates that there will be cavitation phenomenona in the centrifugal pump.

In order to determine whether cavitation will occur in any portion of the suction side of the pump, critical value of Thoma's cavitation factor i.e. **σ** wil be calculated.

Thoma's cavitation factor (σ) for centrifugal pumps

Thoma's cavitation factor will be given by following expression as mentioned here.

$$\sigma = \frac{(H_b) - H_S - h_{LS}}{H} = \frac{(H_{atm} - H_V) - H_S - h_{LS}}{H}$$

Where, H_{atm} = Atmospheric pressure head in m of water or absolute pressure head at the liquid surface in pump

H_V = Vapour pressure head in m of water

H_S = Suction pressure head in m of water

$h_{LS} = h_{fS}$ = Head lost due to friction in suction pipe

H = Head developed by the pump

We will determine the value of Thoma's cavitation factor (σ) and we will compare this value with the value of critical cavitation factor (σ_C) for given centrifugal pump. Critical cavitation factor (σ_C) will be secured by the tables or empirical relationship.
Empirical relationship which is basically used for determination of critical cavitation factor (σ_C) will be given by following equation.

$$\sigma_c = 0.103 \left(\frac{N_s}{1000}\right)^{4/3}$$
$$= 1.03 \times 10^{-3} N_s^{4/3}$$

If the value of Thoma's cavitation factor (σ) is more than the critical cavitation factor (σ_C), cavitation will not occur in the centrifugal pump.
If the value of Thoma's cavitation factor (σ) is less than the critical cavitation factor (σ_C), cavitation will occur in the centrifugal pump.

So, we have seen here the cavitation and its effects in centrifugal pump with the help of this post. We have also introduced here the Thoma's cavitation factor (σ) and critical cavitation factor (σ_C). We have discussed here the case when cavitation will occur in centrifugal pump and when cavitation will not occur in centrifugal pump.

RECIPROCATING PUMP

Reciprocating Pump – Construction and Working

Reciprocating Pump – Construction and Working

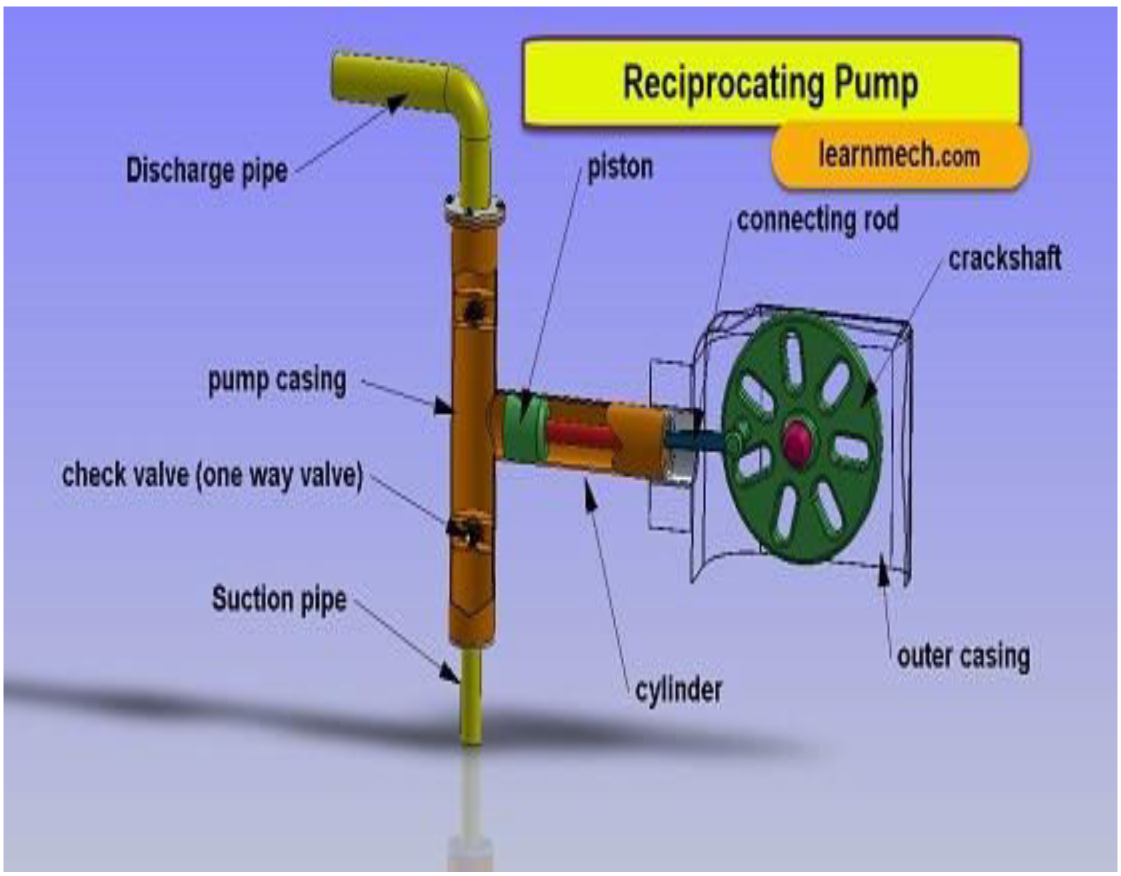
What is a Reciprocating Pump?

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



reciprocating pump – Construction and application

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 is 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.

Working of Reciprocating Pump

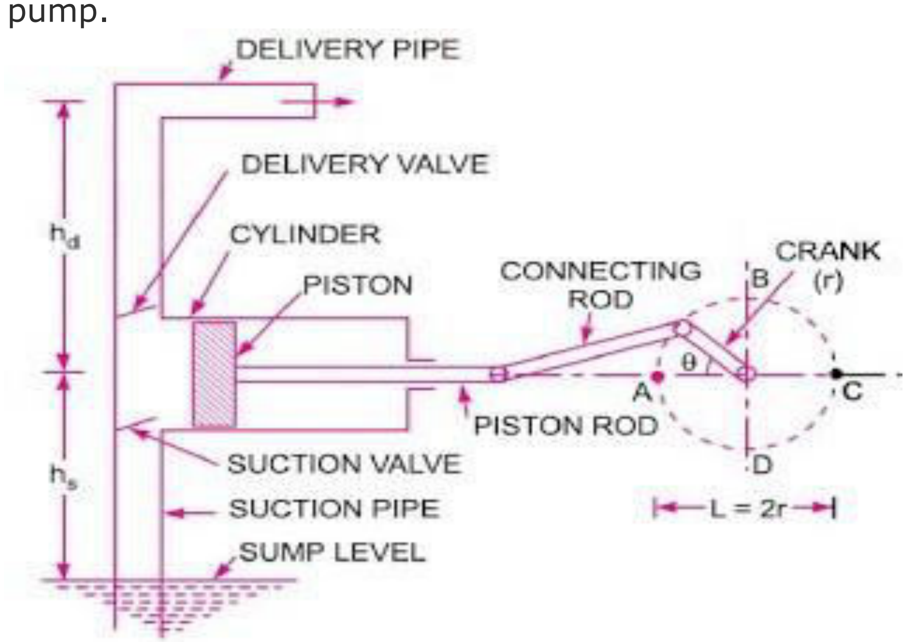
The working of reciprocating pump is as follows:

- 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 into the cylinder.
- 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.

Working principle of reciprocating pump

If the mechanical energy is converted in to stored mechanical energy or pressure energy by sucking the liquid in to a cylinder in which a piston is reciprocating backward and forward, which exerts the thrust on the liquid and increases its hydraulic energy or pressure energy, the hydraulic machine will be termed as reciprocating pump.



There are following main components of a reciprocating pump mentioned here. Following figure displayed here indicates the reciprocating pump.

1. A cylinder with a piston, piston rod, connecting rod, crank and crank shaft
2. Suction pipe
3. Delivery pipe
4. Suction valve

5. Delivery Valve

Above figure indicates the single acting reciprocating pump. Piston will move within a cylinder in forward and backward direction towards inner dead center and outer dead center i.e. piston will execute the reciprocating motion within the tight fit cylinder.

Reciprocating movement of piston within tight fit cylinder will be executed by connecting the piston with crank with the help of connecting rod as displayed in figure. Crank will be fixed with crank shaft which will be rotated by an electric motor.

Suction pipe and delivery pipe will be fixed with the cylinder by means of suction valve and delivery valve respectively as displayed in above figure.

Suction valve and delivery valve will be check valve i.e. non return valve and hence water may flow in one direction only through these valves.

Let us see how a reciprocating pump works

When piston will move towards right i.e. towards outer dead center, there will be fall in pressure of liquid and hence due to reduction in pressure suction valve will be opened and liquid will enter in to the cylinder. This movement of piston inside the cylinder will be termed as suction stroke.

When piston will move towards left i.e. towards inner dead center, there will be increase in pressure of liquid and hence due to increase in pressure of liquid suction valve will be closed and delivery valve will be opened and liquid under high pressure will flow through the delivery valve to delivery pipe of reciprocating pump.

Discharge through a reciprocating pump

Let us consider the following terms as mentioned here for a reciprocating pump displayed above in figure.

D = Diameter of the cylinder
A = Cross sectional area of the piston or cylinder
r = Radius of crank
N = R.P.M of crank
L = Length of the stroke = 2 x r
h_s = Suction head or Height of the cylinder axis from the water surface in the sump
h_d = Discharge head or height of delivery point from the cylinder axis

Volume of water delivered in one revolution = Area x Length of stroke
Volume of water delivered in one revolution = A x L
Number of revolution per second = N/60
Volume of water delivered per second = Volume of water delivered in one revolution x Number of revolution per second

Volume of water delivered per second = A x L x N/60
Volume of water delivered per second = A L N/60

Discharge of the pump per second = A L N/60

Work done by reciprocating pump

Work done by reciprocating pump will be given by following equation as mentioned here

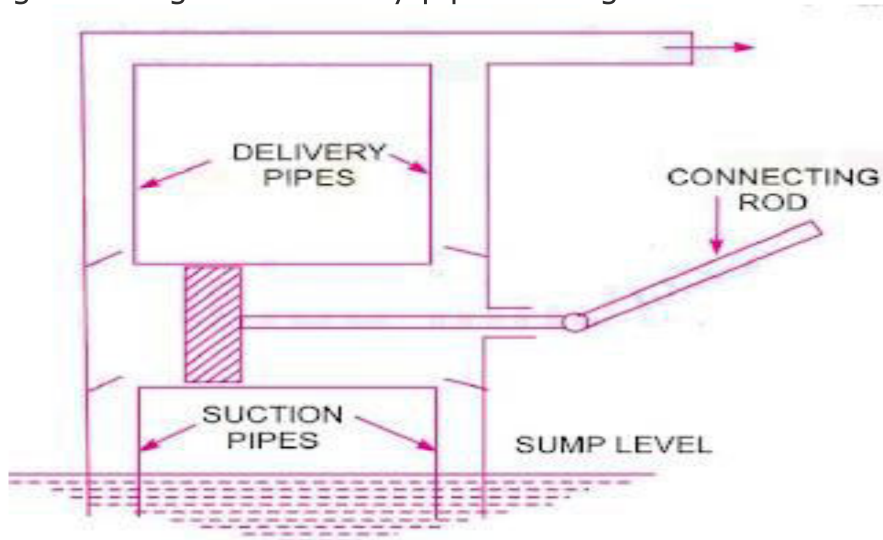
Work done by reciprocating pump = Weight of water lifted per second x Total water through which water is lifted
Work done by reciprocating pump = ρ x g x Discharge of the pump per second x Total water through which water is lifted

Work done by reciprocating pump = ρ g A L N x $(h_s + h_d)$ / 60

DOUBLE ACTING RECIPROCATING PUMP:

Working principle

Water will be acting on both side of the piston in case of double acting reciprocating pump as displayed here in following figure. Therefore, there will be two suction and two delivery pipes for double acting reciprocating pump as shown in following figure.
When there will be a suction stroke on one side of the piston, same time there will be a delivery stroke at the other side of the piston.
Hence, in case of double acting reciprocating pump, there will be two suction strokes and two delivery strokes for one complete revolution of crank and water will be discharged through the delivery pipes during these two delivery strokes.



Let us consider the following terms as mentioned below
D = Diameter of the piston
d = Diameter of the piston rod
Area on one side of the piston, A = $(\pi/4) \times D^2$

Area on other side of the piston where piston rod is connected with piston, $A_1 = (\pi/4) \times [D^2 - d^2]$

Discharge of the double acting reciprocating pump

Volume of water delivered in one revolution of the crank will be determined as mentioned below

$$V = A \times \text{Length of stroke} + A_1 \times \text{Length of stroke}$$

$$V = AL + A_1 L = (A + A_1)L = \left[\frac{\pi}{4}D^2 + \frac{\pi}{4}\left(D^2 - d^2\right)\right] \times L$$

Discharge of pump in one revolution of the crank will be determined as mentioned below

Discharge of pump = Volume of water delivered in one revolution X No. of revolution in one second

$$\text{Discharge of pump} = \left[\frac{\pi}{4}D^2 + \frac{\pi}{4}\left(D^2 - d^2\right)\right] \times L \times \frac{N}{60}$$

If diameter of the piston rod i.e. d is very small as compared to the diameter of the piston i.e. D, then we can neglect it and discharge of the pump could be written as mentioned below.

$$\text{Discharge of pump per second } Q = \left(\frac{\pi}{4}D^2 + \frac{\pi}{4}D^2\right) \times \frac{L \times N}{60} = 2 \times \frac{\pi}{4}D^2 \times \frac{L \times N}{60} = \frac{2ALN}{60}$$

$$\text{Discharge of pump per second } Q = \frac{2ALN}{60}$$

Above equation is the equation for the discharge of the double acting reciprocating pump. We can say that, discharge of the double acting reciprocating pump will be double of the discharge of the single acting reciprocating pump.

Work done by double acting reciprocating pump

Work done per second = Weight of water delivered x total height

$$\text{Work done per second} = 2\rho g \times \frac{ALN}{60} \times (h_s + h_d)$$

Power required to drive the double acting reciprocating pump

Power required to drive the pump will be given by following equation as mentioned below

$$P = \frac{2\rho g \times ALN \times \left(h_s + h_d\right)}{60{,}000}$$

Slip in reciprocating pump

Slip in reciprocating pump is basically defined as the difference between the theoretical discharge and actual discharge of the reciprocating pump.

Actual discharge of a reciprocating pump will be less than the theoretical discharge of the pump due to leakage of water during operation of pump.

The difference of the theoretical discharge and actual discharge will be called as slip of reciprocating pump.

Mathematically, we can express the slip in reciprocating pump as mentioned below

$$\textbf{Slip} = Q_{th} - Q_{act}$$

Slip is usually expressed as percentage slip and it will be given by following expression.

$$\text{Percentage slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100 = \left(1 - \frac{Q_{act}}{Q_{th}}\right) \times 100$$

$$= (1 - C_d) \times 100$$

Where, C_d = Co-efficient of discharge

Theoretical discharge of a single acting reciprocating pump

Discharge of the pump per second,Q **= A L N/60**

Theoretical discharge of a double acting reciprocating pump

$$\text{Discharge of pump per second } Q = \frac{2ALN}{60}$$

Negative slip in reciprocating pump

As we have discussed above that slip in reciprocating pump is basically the difference between the theoretical discharge and actual discharge of the reciprocating pump. If actual discharge is more than the theoretical discharge, slip of the reciprocating pump will be negative and it could be concluded by considering the equation of slip of reciprocating pump.

Negative slip will occur when suction pipe is long, delivery pipe is short and pump is running at high speed.

Uses of Reciprocating Pump

Reciprocating pump is mainly used for

- Oil drilling operations
- Pneumatic pressure systems
- Light oil pumping
- Feeding small boilers condensate return

Advantages of Reciprocating Pump

1. This pump is self-priming – Not require filling the cylinders by starting.
2. This pump can work in wide pressure range.
3. Priming is not necessary in pump.
4. Provide high pressure at outlet.
5. Provide elevated suction lift.
6. They are use for air also.

Disadvantages of Reciprocating pump

1. Flow is not consistent, so we have to fit a bottle at equally ends.
2. Flow is extremely less and cannot use for high flow process.
3. High wear and tear, so need lot maintenance.
4. Early price is much more in this pump.
5. Additional heavy and large in shape.
6. Low discharging capacity.

Difference between Centrifugal Pump and Reciprocating Pump:

S. No.	Centrifugal pump	Reciprocating pump
1.	It is one of the rotary pumps which used kinetic energy of impeller.	It is a positive displacement type pump which is forced by piston.
2.	It continuously discharges the fluid.	It does not discharge the fluid continuously.
3.	In centrifugal pump the flow rate decreases which increasing the pressure.	The pressure does not affect flow rate in reciprocating pumps.
4.	It is used for pumping high viscous fluid.	It is used for pump low viscous fluid.
5.	In this pumps discharge is inversely promotional to the viscosity of fluid.	In reciprocating pump viscosity of fluid does not affect the discharge rate.
6.	Efficiency of these pumps are low compare to reciprocating pump.	Efficiency is high.
7.	Centrifugal pump have problem of priming.	It does not have any problem of priming.
8.	It uses impellers to transfer energy to fluid.	It uses piston cylinder device to transfer energy to fluid.
9.	They are lighter than reciprocating pumps.	These are heavier compare to centrifugal pump.
10.	It gives higher discharge at low heads.	These gives higher heads at low discharge.
11.	It is less costly.	These are costly.
12.	These pumps required less maintenance.	These required higher maintenance.
13.	Centrifugal pumps are easy to install. These required less floor space.	These pumps are difficult to install. These required more floor area.
14.	It is mostly used for domestic purpose and where higher discharge at low head required.	These are mostly used in industries and high viscous fluid pumped at a high head.

Application Of Fluid Power

Introduction

In the industry we use three methods for transmitting power from one point to another. Mechanical transmission is through shafts, gears, chains, belts, etc. Electrical transmission is through wires, transformers, etc. Fluid power is through liquids or gas in a confined space. In this chapter, we shall discuss a structure of hydraulic systems and pneumatic systems. We will also discuss the advantages and disadvantages and compare hydraulic, pneumatic, electrical and mechanical systems.

Fluid power applications can be classified into two major segments:

Stationary hydraulics:

Stationary hydraulic systems remain firmly fixed in one position. The characteristic feature of stationary hydraulics is that valves are mainly solenoid operated.

The applications of stationary hydraulics are as follows:

- Production and assembly of vehicles of all types.
- Machine tools and transfer lines.
- Lifting and conveying devices.
- Metal-forming presses.
- Plastic machinery such as injection-molding machines.
- Rolling machines.
- Lifts.
- Food processing machinery.
- Automatic handling equipment and robots.

Mobile hydraulics:

Mobile hydraulic systems move on wheels or tracks such as a tower crane or excavator truck to operate in many different locations or while moving. A characteristic feature of mobile hydraulics is that the valves are frequently manually operated. The applications of mobile hydraulics are as follows:

- Automobiles, tractors, aeroplanes, missile, boats, etc.
- Construction machinery.
- Tippers, excavators and elevating platforms.
- Lifting and conveying devices.

- Agricultural machinery.

Hydraulics and pneumatics have almost unlimited application in the production of goods and services in nearly all sectors of the country. Several industries are dependent on the capabilities that fluid power affords. Table summarizes few applications of fluid power.

More applications of fluid power

Agriculture – Tractors; farm equipment such as mowers, ploughs, chemical and water sprayers, fertilizer spreaders, harvesters Automation Automated transfer lines, robotics

Automobiles – Power steering, power brakes, suspension systems, hydrostatic transmission

Aviation- Fluid power equipment such as landing wheels in aircraft. Helicopters, aircraft trolleys, aircraft test beds, luggage loading and unloading systems, ailerons, aircraft servicing, flight simulators

Construction industry/equipment – For metering and mixing of concrete rudders, excavators,
lifts, bucket loaders, crawlers, post-hole diggers, road graders, road cleaners, road maintenance vehicles, tippers

Defense – Missile-launching systems, navigation controls.

Fabrication industry – Hand tools such as pneumatic drills, grinders, borers, riveting machines, nut runners

Food and beverage – All types of food processing equipment, wrapping, bottling,

Foundry – Full and semi-automatic molding machines, tilting of furnaces, die-casting machines

Glass industry – Vacuum suction cups for handling

Hazardous gaseous areas – Hydraulic fracturing technologies: It involves pumping large volumes of water and sand into a well at high pressure to fracture shale and other tight formations, allowing hazardous oil and gas to flow into the well. However, hydraulic fracturing has serious environmental and water pollution related issues.

Instrumentation – Used to create/operate complex instruments in space rockets, gas turbines, nuclear power plants, industrial labs

Jigs and fixtures – Work holding devices, clamps, stoppers, indexers

Machine tools – Automated machine tools, numerically controlled(NC) machine tools

Materials handling – Jacks, hoists, cranes, forklifts, conveyor systems

Medical – Medical equipment such as breathing assistors, heart assist devices, cardiac compression machines, dental drives and human patient simulator

Movies – Special-effect equipment use fluid power; movies such as Jurassic park, Jaws, Anaconda, Titanic

Mining- Rock drills, excavating equipment, ore conveyors, loaders.

Press tools – Heavy duty presses for bulk metal formation such as sheet metal, forging, bending, punching, etc.

Printing industry – For paper feeding, packaging

Robots – Fluid power operated robots, pneumatic systems

Ships – Stabilizing systems, unloading and loading unit, gyroscopic instruments, movement of flat forms, lifters, subsea inspection equipment

Textiles – Web tensioning devices, trolleys, process controllers Transportation Hydraulic elevators, winches, overhead trams

Under sea -Submarines, under sea research vehicles, marine drives and control of ships

Wood working- Tree shearers, handling huge logs, feeding clamping and saw operations

Difference Between Power System | Mechanical , Hydraulic , Electrical , Pneumatic

There are three basic methods of transmitting power: electrical, mechanical and fluid power. Most applications actually use a combination of the three methods to obtain the most efficient overall system. To properly determine which method to use, it is important to know the salient features of each type. For example, fluid systems can transmit power more economically over greater distances than mechanical types. However, fluid systems are restricted to shorter distances compared to electrical systems. Table

Mechanical Power System :

Mechanical power transmission refers to products used in systems with moving parts as opposed to systems powered electrically. These products include shaft couplings, chains and sprockets, belts and sheaves, and drive components.

Belts, such as v-belts and synchronous drive belts, are used in a variety of applications and work in conjunction with pulleys and sheaves. These products reduce slippage and are commonly used in manufacturing, HVAC, and agricultural industries. Shaft couplings join two shafts together and are available in two main types: flexible shaft couplings and rigid shaft couplings. Drive components include clutches, breaks, gears, and variable speed motor drives.

Electric power system

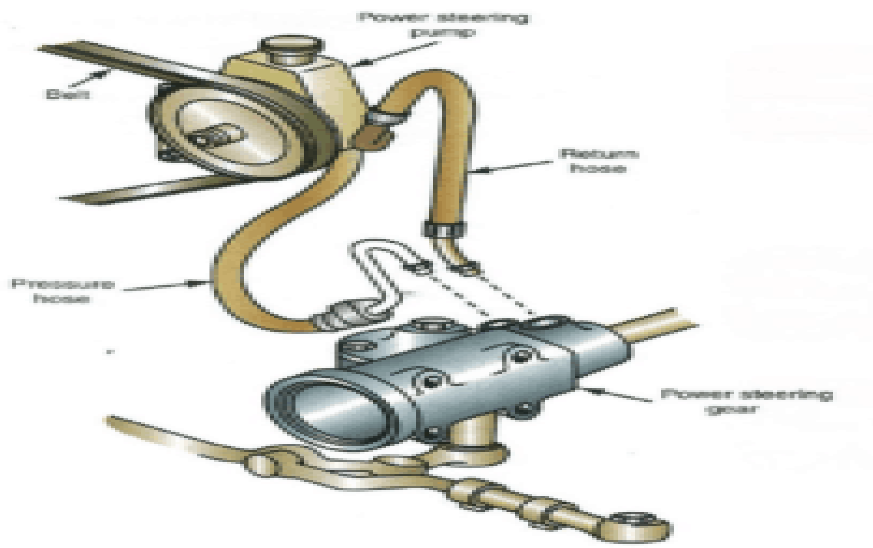
An electric power system is a network of electrical components deployed to supply, transfer, and use electric power. An example of an electric power system is the grid that provides power to an extended area. An electrical grid power system can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres, and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power—the standard for large-scale power transmission and distribution across the modern world. Specialised power systems that do not always rely upon three-phase AC power are found in aircraft, electric rail systems, ocean liners and automobiles.

Hydraulic and Pneumatic Power system :

Pneumatic technology deals with the study of behavior and applications of compressed air in our daily life in general and manufacturing automation in particular. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

Hydraulic System:

The controlled movement of parts or a controlled application of force is a common requirement in the industries. These operations are performed mainly by using electrical machines or diesel, petrol and steam engines as a prime movers. These prime movers can provide various movements to the objects by using some mechanical attachments like screw jack, lever, rack and pinions etc. However, these are not the only prime movers. The enclosed fluids (liquids and gases) can also be used as prime movers to provide controlled motion and force to the objects or substances. The specially designed enclosed fluid systems can provide both linear as well as rotary motion. The high magnitude controlled force can also be applied by using these systems. This kind of enclosed fluid based systems using pressurized incompressible liquids as transmission media are called as hydraulic systems. The hydraulic system works on the principle of Pascal’s law which says that the pressure in an enclosed fluid is uniform in all the directions.



Integral power-assisted steering system.

Comparison of different power systems

Property	**Mechanical**	**Electrical**	**Pneumatic**	**Hydraulic**
Input energy source	I C engines Electric motor	I C engines Water/gas turbines	I C engines Pressure tank	I C engines Electric motor Air turbine
Energy transfer element	Levers, gears, shafts	Electrical cables and magnetic field	Pipes and hoses	Pipes and hoses
Energy carrier	Rigid and elastic objects	Flow of electrons	Air	Hydraulic liquids

Property	Mechanical	Electrical	Pneumatic	Hydraulic
Power-to-weight ratio	Poor	Fair	Best	Best
Torque/inertia	Poor	Fair	Good	Best
Stiffness	Good	Poor	Fair	Best
Response speed	Fair	Best	Fair	Good
Dirt sensitivity	Best	Best	Fair	Fair
Relative cost	Best	Best	Good	Fair
Control	Fair	Best	Good	Good
Motion type	Mainly rotary	Mainly rotary	Linear or rotary	Linear or rotary

Introduction To Pneumatic System And Components Used in Pneumatic system

Pneumatic technology deals with the study of behavior and applications of compressed air in our daily life in general and manufacturing automation in particular. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

Basic Components of Pneumatic System:

Important components of a pneumatic system are shown in fig.

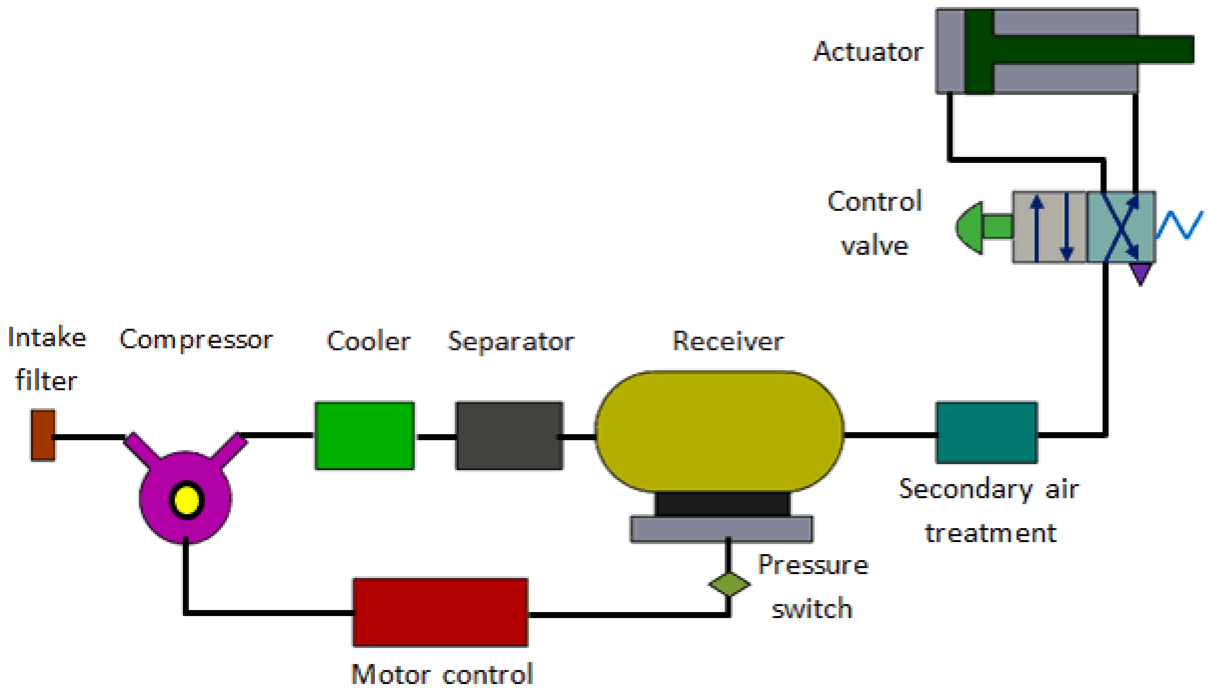


Fig: Pneumatic system

1. **Air filters:**These are used to filter out the contaminants from the air.
2. **Compressor:** Compressed air is generated by using air compressors. Air compressors are either diesel or electrically operated. Based on the requirement of compressed air, suitable capacity compressors may be used.
3. **Air cooler:**During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air.
4. **Dryer:** The water vapor or moisture in the air is separated from the air by using a dryer.
5. **Control Valves:**Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.
6. **Air Actuator:**Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.
7. **Electric Motor:**Transforms electrical energy into mechanical energy. It is used to drive the compressor.
8. **Receiver tank :**The compressed air coming from the compressor is stored in the air receiver.

Note: In advance system **FRL unit** is used -F means filter, R means Regulator, L means Lubricator. in above figure this unit is shown separately but function of this sub parts remain same.

Pressure Relief Valve – Diagram , Working

Introduction

Hydraulic energy is produced as long as the prime mover (usually an electric motor) drives the pump, and hydraulic pressure develops by resistance to pump flow.Hence, the hydraulic system suffers damage if the pump flow is not stopped or off loaded (recirculate) back to the tank during non-action periods of the circuit.Non-action periods arise from stalling an actuator, or by reaching the end of the stroke or the
circuit sequence, or during the time-delay periods of the circuit sequence.
In order to avoid hydraulic system damage, power wastage and overheating of the hydraulic fluid, circuit designers use a variety of cleverly designed systems to control maximum system pressure and pump flow during non-action periods.

Pressure-Relief Valves

Pressure-relief valves limit the maximum pressure in a hydraulic circuit by providing an alternate path for fluid flow when the pressure reaches a preset level. All fixed-volume pump circuits require a relief valve to protect the system from excess pressure. Fixed-volume pumps must move fluid when they turn. When a pump unloads through an open-center circuit or actuators are in motion, fluid movement is not a
problem. A relief valve is essential when the actuators stall with the directional valve still in shifted position.

A relief valve is similar to a fuse in an electrical system. When circuit amperage stays below the fuse amperage, all is well. When circuit amperage tries to exceed fuse amperage, the fuse blows and disables the circuit. Both devices protect the system from excess pressure/current by keeping it below a preset level. The difference is that when an electrical fuse blows, it must be reset or replaced by maintenance personnel before the machine cycles again. This requirement alerts electrician’s about a possible problem before restarting the machine. Without the protection of a fuse, the electrical circuit would finally overheat and start a fire.

Similarly, in a hydraulic circuit, a relief valve opens and bypasses fluid when pressure exceeds its setting. The valve then closes again when pressure falls. This means that a relief valve can bypass fluid anytime, or all the time, without intervention by maintenance. Many fixed-volume pump circuits depend on this bypassing capability during the cycle, and some even bypass fluid during idle time. A well-designed
circuit never bypasses fluid unless there is a malfunction, such as a limit switch not closing or an operator over-riding the controls. This eliminates most overheating problems and saves energy.

There are two different designs of relief valves in use: direct-acting and pilot-operated. Both types have advantages and work better in certain applications.

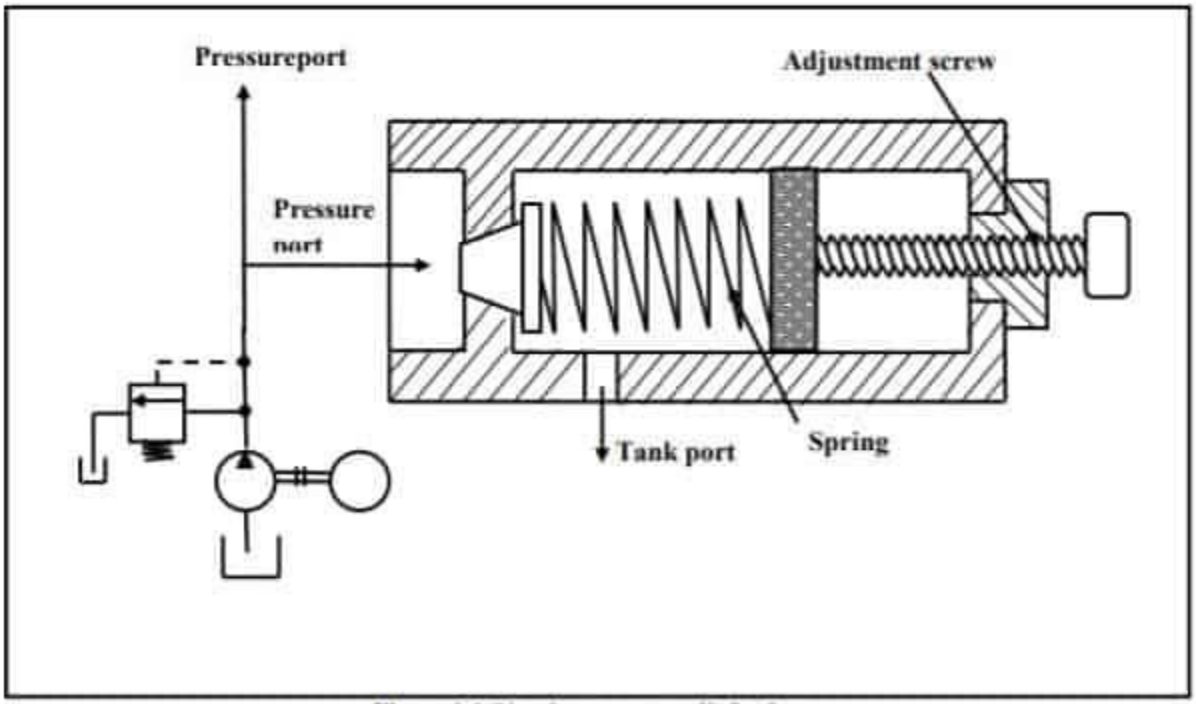


Figure1.1 Simple pressure-relief valve.

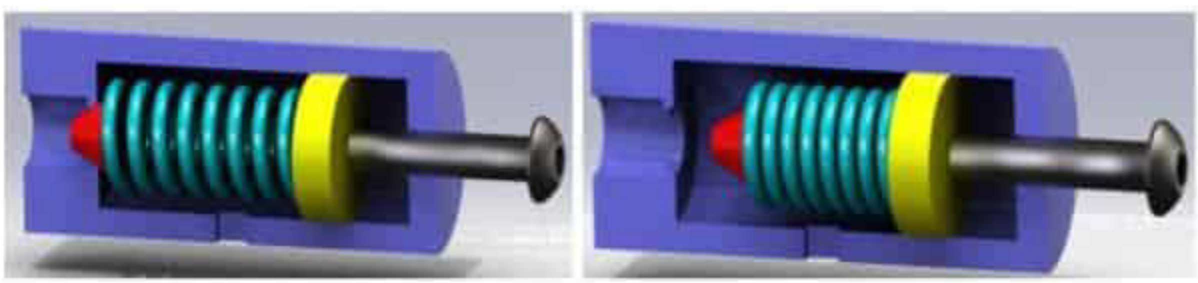


Figure 1.2 Three-dimensional view of simple pressure-relief valve.

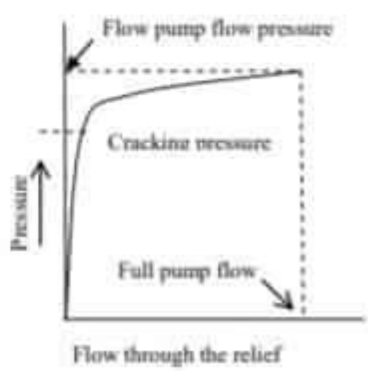


Figure 1.3 Characteristics of a relief valve.

relief Valve

Simple Pressure-Relief Valve

The most widely used type of pressure control valve is the pressure-relief valve because it is found in practically every hydraulic system. Schematic diagram of simple relief valve is shown in Fig. 1.1 and three-dimensional view is shown in Fig. 1.2. It is normally a closed valve whose function is to limit the pressure to a specified maximum value by diverting pump flow back to the tank. A poppet is held seated
inside the valve by a heavy spring. When the system pressure reaches a high enough value, the poppet is forced off its seat. This permits flow through the outlet to the tank as long as this high pressure level is maintained. Note the external adjusting screw, which varies spring force and, thus, the pressure at which the valve begins to open (cracking pressure)(Fig. 1.3).
It should be noted that the poppet must open sufficiently to allow full pump flow. The pressure that exists at full pump flow can be substantially greater than cracking pressure. The pressure at full pump flow is the pressure level that is specified when referring to the pressure setting of the valve. It is the maximum pressure level permitted by the relief valve.

If the hydraulic system does not accept any flow, then all the pump flow must return to the tank via the relief valve. The pressure-relief valve provides protection against any overloads experienced by the actuators in the hydraulic system. Of course, a relief valve is not needed if a pressure-compensated vane pump is used. Obviously one important function of a pressure-relief valve is to limit the force or torque produced by hydraulic cylinders or motors.

Advantages Of Relief Valve :

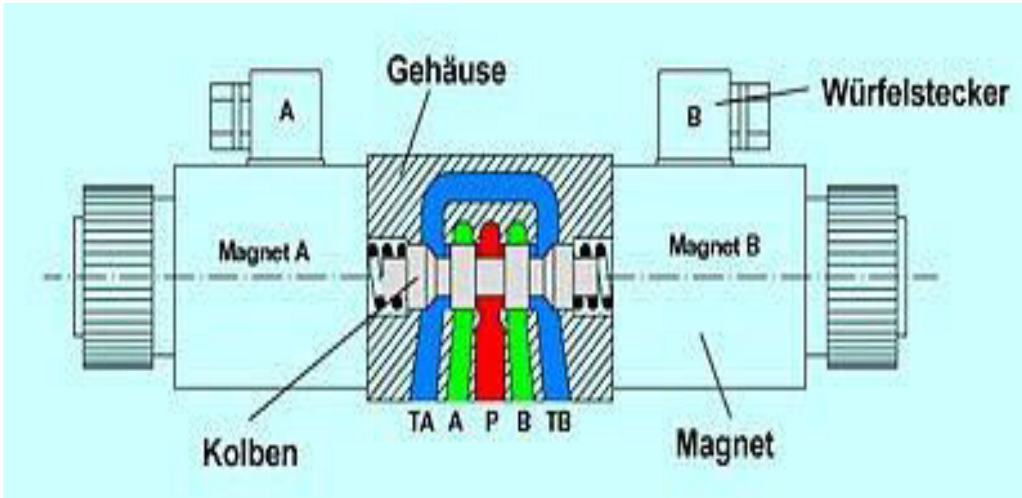
The main advantage of direct-acting relief valves over pilot-operated relief valves is that they respond very rapidly to pressure buildup. Because there is only one moving part in a direct-acting relief valve, it can open rapidly, thus minimizing pressure spikes.

What is Direction Control Valve | Types Of DCV in Fluid System

What are Directional Control Valves ?

As the name suggests, the function of a directional control valve (DCV) is to control the direction of flow in a hydraulic circuit. ;
In other words, directional control valves (DCFs) regulate the direction in which the I fluidflows in a hydraulic circuit. ;
In addition to controlling direction of actuator motion, the directional valves are also used to select alternate control circuits, and (zr) to perform logic control functions.
These valves are not intended to change the rate of flow of fluid; but they are either completely open or completely closed. They can be actuated to switch the fluid flow direction by various actuating means such as electrical,

mechanical or fluid pressure signals. This results in corresponding connection or disruption of flow between various port openings.



Direction Control Valve

Classification of Directional Control Valves

The directional control valves can be classified in many different ways.

1. The directional control valves are basically classified, according to the construction into three groups, as

1. Poppet (or seat) valves,
2. Sliding spool valves, and
3. Rotary spool valves.

2. Based on the number of ports' present, the directional control valves may be classified as

(1) Two way valves,
(2) Three way valves, and
(3) Four way valves. .

3. Based on the mode of actuation, the directional control valves can be classified as :

(1) Manually operated directional valves,
(2) Mechanically operated directional valves,
(3) Solenoid operated directional valves, and
(4) Pilot operated directional valves. .

4. However, for our study we can classify the directional control valves into three :

1. Check valves,
2. Position valves, and
3. Shuttle valves.

Specification

Diectional Control Valves are generally specified using the number of ports and the number of switching positions. It can be represented in general form as np/ns, where np is the number of ports connected to the direction control valve and ns the number of switching positions.

In addition, the method of actuation and the return method can also be specified. A hypothetical valve could be specified as 4-way, 3-position direction control valve or 4/3 DCV since there are four ports and three switching positions for the valve. In this example, one port is called the pressure port which is connected to the pump; one port is the tank port and is connected to the tank (or reservoir); and the two remaining ports are called working ports and are connected to the actuator. Apart from characteristics of valve the fluid suitable for valve, working temperature and viscosity also thought upon before selecting a particular type of valve.

ISO Symbols of Pneumatic Components

Symbols are used as a system of shorthand iconography that's shared within an industry or functional system across the world – like traffic lights. Drivers everywhere know that red means stop and green means go. Pneumatic symbols are simply that specific set of symbols which have been devised for use in the pneumatics industry.

Pneumatic symbols were principally created to identify components on circuit design diagrams, but they can also be used on the components themselves. On a valve, for example, there will be a manufacturer's label carrying pressure and power information, as well as a small diagram of how many ports and outlets it has and how they work. The fixed dimension ratios of the diagrams may be slightly variable, as they were originally intended solely for use in data processing.

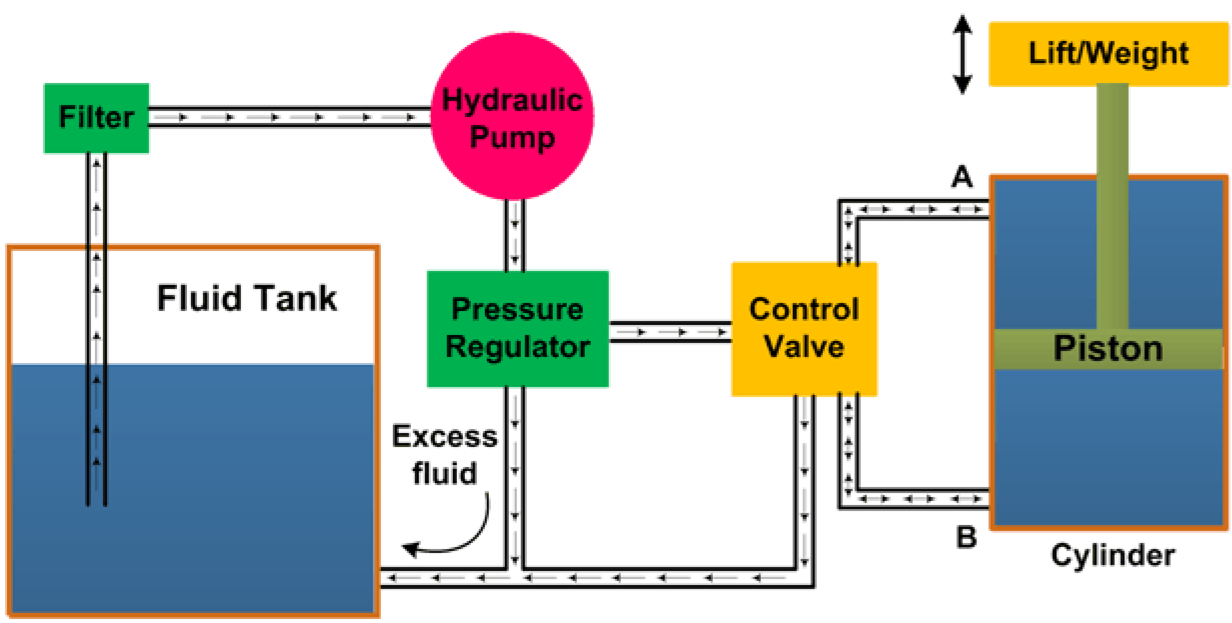
INTRODUCTION TO HYDRAULIC CIRCUIT (SYSTEM)

Hydraulic System:

The controlled movement of parts or a controlled application of force is a common requirement in the industries. These operations are performed mainly by using electrical machines or diesel, petrol, and steam engines as prime movers. These prime movers can provide various movements to the objects by using some mechanical attachments like screw jack, lever, rack and pinions etc. However, these are not the only prime movers. The enclosed fluids (liquids and gases) can also be used as prime movers to provide controlled motion and force to the objects or substances. The specially designed enclosed fluid systems can provide both linear as well as rotary motion. The high magnitude controlled force can also be applied by using these systems. This kind of enclosed fluid-based systems using pressurized incompressible liquids as transmission media are called as hydraulic systems. The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions.

The hydraulic systems consists a number of parts for its proper functioning. These include storage tank, filter, hydraulic pump, pressure regulator, control valve, hydraulic cylinder, piston, and leak-proof fluid flow pipelines. The schematic of a simple hydraulic system is shown in figure.
It consists of:

- **a movable piston connected to the output shaft in an enclosed cylinder**
- **storage tank**
- **filter**
- **electric pump**
- **pressure regulator**
- **control valve**
- **leak proof closed-loop piping.**



hydraulic System

The output shaft transfers the motion or force however all other parts help to control the system. The storage/fluid tank is a reservoir for the liquid used as a transmission media. The liquid used is generally high-density incompressible oil. It is filtered to remove dust or any other unwanted particles and then pumped by the hydraulic pump. The capacity of the pump depends on the hydraulic system design. These pumps generally deliver constant volume in each revolution of the pump shaft. Therefore, the fluid pressure can increase indefinitely at the dead-end of the piston until the system fails. The pressure regulator is used to avoid such circumstances which redirect the excess fluid back to the storage tank. The movement of the piston is controlled by changing the liquid flow from port A and port B. The cylinder movement is controlled by using a control valve which directs the fluid flow. The fluid pressure line is connected to the port B to raise the piston and it is connected to port A to lower down the piston. The valve can also stop the fluid flow in any of the ports. The leak-proof piping is also important due to safety, environmental hazards, and economic aspects. Some accessories such as flow control system, travel limit control, electric motor starter, and overload protection may also be used in the hydraulic systems which are not shown in the figure .

Hydraulic Circuit – Hydraulic Layout Diagram

Components of Hydraulic System

Basic hydraulic system has the following components:

1) Oil reservoir
2) Rotary pump
3) Pressure relief valve
4) Direction control valve
5) Flow control valve
6) Double-acting cylinder
7) Pressure gauge
8) Filter

1) Oil Reservoir

- The main function of the “oil reservoir” is to store a sufficient amount of hydraulic oil in the system.

Apart from this, it has other important functions such as:

(a) To cool the hot return oil.
(b) To settle down the contaminants
(c) To remove air bubbles.
(d) To separate water from the oil etc.

2) Rotary pump

- The function of the rotary pump is to pump hydraulic oil to the hydraulic circuit’
- It converts the mechanical energy (rotation of shaft) into hydraulic energy

- A rotary pump is a positive displacement pump. It can deliver constant flow even at high pressure

3) Pressure relief valve

- It is an important component which is required for every positive displacement pump
- This valve is connected to the outlet of the pump. Its main function is to release the oil back tank when the pressure increases beyond pre-set value.

4) Direction control valve

- It controls the direction of flow of oil, by which it performs extension and retraction of the actuator

5) Flow control valve

- It Controls the rate of flow of oil by which the speed of extension or retraction of the actuator is controlled.

6) Actuator

- Actuator produces work. There are two types, linear actuator and rotary actuator
- A linear actuator is called a cylinder, a rotary actuator is called a motor.
- A double-acting cylinder develops force and motion. It converts hydraulic energy into mechanical energy

Force developed = Pressure of oil x Area of piston

7) Pressure gauge

- It is an important component of the hydraulic system.
- It shows the pressure reading.
- Pressure settings are made by looking to the pressure gauge.
- Without pressure gauge, it is not possible to make the pressure relief valve setting, unloading valve settings etc.

8) Filter

- Its main function is to remove suspended solid contaminants from the oil and to provide clean hydraulic oil to the system

Applications of hydraulic systems

1. Machine tools: CNC (computerized numerical control) machines, hydraulic presses, hydraulic shapers, etc.
2. Material handling equipment: Elevators, forklifts, cranes, lifts and hoists etc.

3. Construction field: Earthmoving machines such as excavators, cranes, dozers, loaders, dumpers, tippers, trucks, tractors, etc.
4. Automobiles: Hydraulic brakes, hydraulic steering, hydraulic suspension, hydraulic
clutch, hydraulic power transmission, hydraulic coupling,
5. Material testing laboratory: UTM (universal testing machine) and other destructive testing Machines, BP (burst pressure) testing machine etc.
6. Aerospace: Landing gear, brakes, flight controls (such as), cargo loading door, rudder, elevator, flap, aileron, etc.
7. Railways: Hydraulic brakes, hydraulic steering, hydraulic suspension, hydraulic clutch, hydraulic power transmission, hydraulic coupling hydraulic torque converter, etc.
8. Marine field: Ship steering system, ship-yards, ship-building.
9. Medical equipment: Medical chairs and operating tables.
1**0. Agricultural equipment:** Harvesters, tractors, field sprayers, seeding machine, fertilizer machine etc.

Advantages and Disadvantages of Hydraulic system

Advantages of Hydraulic System :

The basic advantages offered by a hydraulic system are as follows:
l. Hydraulic power is easy to produce, transmit, store, regulate and control, maintain and transform
2. Weight to power ratio of a hydraulic system is comparatively less than that for an electromechanical system. (About 8.5 kg/kw for electrical motors and 0.g5 kg/kw for a hydro system).
3. It is possible to generate high gain in force and power amplification.
4. Hydraulic systems are uniform and smooth, generate step-less motion and variable speed and force to a greater accuracy.
5. The division and distribution of hydraulic power is simpler and easier than other forms of energy.
6. Limiting and balancing of hydraulic forces are easily performed.
7. Frictional resistance is much less in a hydraulic system as compared to a mechanical movement.
8. Hydraulic elements can be located at any place and controlled reversely.
9. The noise and vibration produced by hydraulic pumps is minimal.
10. Hydraulic systems are cheaper if one considers the high efficiency -of power transmission.
I l. Easy maintenance of hydraulic system is another advantage.
12. Hydraulics is mechanically safe, compact, and is adaptable to other forms of power and can be easily controlled.
13. Hydraulic output can be both linear, rotational, and angular. The use of flexible connections in the hydraulic system permits the generation of compound motion without gears etc.
14. Hydraulics is a better over-load safe power system. This can be easily achieved by using a pressure relief valve.
15. Absolutely accurate feedback of load, position, etc. can be achieved in a hydraulic system as in electro-hydraulic and digital electronic servo system. Because of high power and accurate control possibility, in modem engineering

language hydraulics is termed as the muscle of the system and electronics its nerves.

Disadvantages of Hydraulic System :

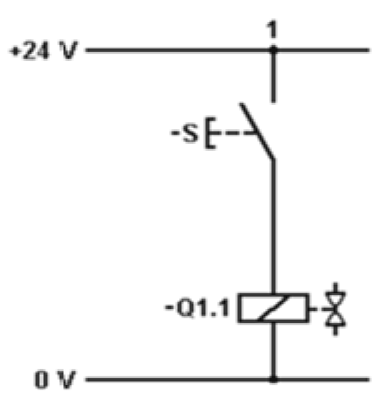
In spite of all the above advantages, hydraulic systems have some drawbacks which are mentioned below.
The disadvantages are:
1. Hydraulic elements have to be machined to a high degree of precision which increases the manufacturing cost of the system.
2. Certain hydraulic systems are exposed to unfriendly climate and dirty atmosphere as the in case of mobile hydraulics like dumpers, loaders, etc.
3. The leakage of hydraulic oil poses problems to hydraulic users.
4. Hydraulic elements have to be specially treated to protect them against rust, corrosion, dirt, etc.
5. Hydraulic oil may pose problems if it disintegrates due to aging and chemical deterioration.
6. Petroleum-based hydraulic oil may pose fire hazards thus limiting the upper level of working temperature. However, due to the availability of synthetic fire-resistant oils this problem is of academic interest nowadays. To combat the environmental effects of petroleum and chemical-based oils, efforts are on to use biodegradable oils now.

Direct and Indirect Control of Single Action Cylinder

In a relay-controlled system, electrically operated directional control valves can either be activated directly or indirectly. This example considers the control of a single-action cylinder via a 3/2 directional control valve.

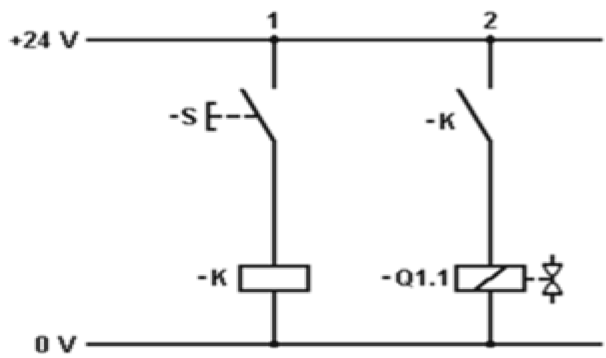
Direct Control

The graphic below shows the electrical component of an electro-pneumatic control system that directly controls a cylinder (the pneumatic component of the system is not illustrated). Pressing the button S closes circuit 1 and solenoid Q1.1 of the directional control valve is supplied with power. The magnet is drawn in, switching the valve to its operating position causing the cylinder to extend. When the button is released, the circuit opens, the electromagnet releases and the valve returns to its rest position.



Indirect Control

The circuit below illustrates indirect control of a cylinder (with its more complex circuitry). The current to the coil of the solenoid is not directly applied via the switch S but indirectly via an intermediate relay K



Indirect control has the following advantages over direct control:

Control circuit 1 and main circuit 2 can operate at different voltages (e.g. 24 V and 220 V).

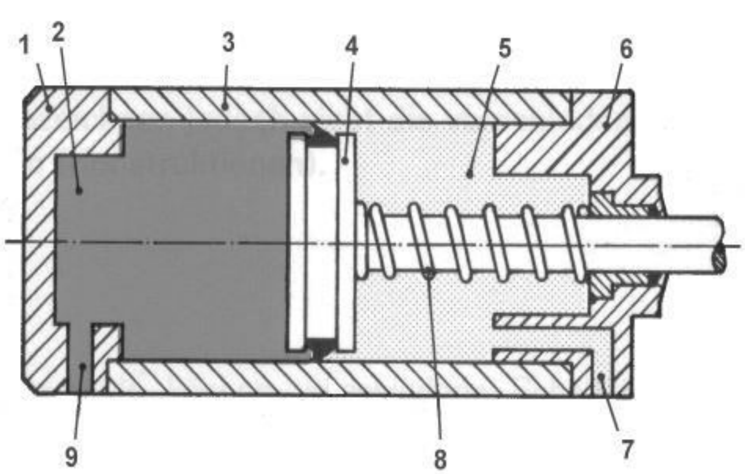
The current in the solenoid of the valve can be greater than the maximum permissible for the switch S.

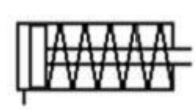
One switch can simultaneously control more than one valve (by means of a relay with an appropriate number of contacts).

Extensive links between signals from various switches can be implemented.

<u>Design of a Single-Acting Cylinder</u>

The following graphic shows the design of a single-acting cylinder with return spring and the relevant symbol according to DIN ISO 1219-1.





(1) Base

(2) Side of piston

(3) Cylinder tube

(4) Piston with piston rod and seal

(5) Side of rod

(6) Cover

(7) Exhaust

(8) Return spring

(9) Air inlet

If compressed air of pressure p_e is supplied to the cylinder via the air inlet, the piston surface A is subjected to a force of

$F = p_e . A$

The amount of mechanical work then performed is proportional to the stroke length 's'

$W = F . s$

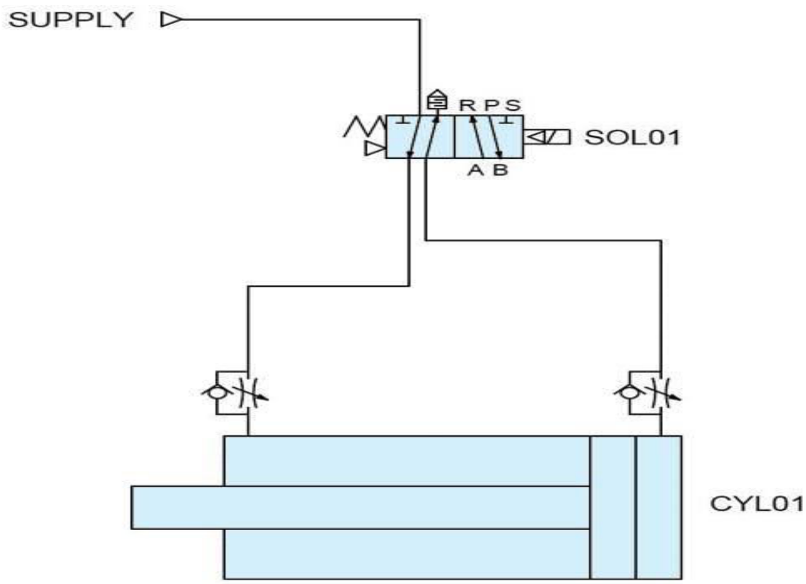
Single-acting cylinders are only able to do work in one direction. This means they are suitable for charging, ejecting, pressing, lifting and feeding.

How the cylinder Works:

Compressed air flows via the air-inlet into cylinder on the side of the piston, in the process of which pressure p builds up over the surface of the piston generating a force F that is proportional to the pressure. This pressure causes the piston and piston rod to move (extend). Once the piston has reached full extension, the pressure builds up to full operating pressure. After the pressure has fallen the reset spring restores the piston to its initial operating position (return action). As the force of the spring resists the motion during forward motion phase, it is only designed to be strong enough to return the piston back into its initial position and is thus normally unable to return any heavy items connected to the piston rods to their initial position. It is also important to keep the length of the stroke sufficiently restricted as otherwise the force of the spring would continue to increase the longer the stroke length becomes.

Double-Acting Cylinder

The schematic below shows a common automation application: using a 4-way solenoid valve (SOL01) to extend and retract a double-acting cylinder (CYL01). Triangles at each side of the symbol indicate it is a pilot-activated, single-solenoid, spring-return valve.



Double-acting cylinder circuits are common on PLC-controlled machines.

Filtered air feeds the solenoid valve, which is usually energized by a 24 V dc PLC output. This activates the valve and lets air leave through port B and flow freely through the flow control to extend the cylinder rod and plunger to the left. Air on the left side of the cylinder is forced out through its flow control to the valve's port A, and then goes to port R and exits through a muffler to reduce exhaust noise.

Pilot valves need only a small amount of air to efficiently move a large valve spool. However, valves require a minimum operating pressure, typically about 20 psi, to move the spool. A spring on the left side pushes the valve spool to the right to maintain its normal off or resting state. With the valve off, air flows out of port A and freely through the adjustable flow control to the left side of the cylinder (CYL01), making it retract.

As the cylinder retracts, air on the right side leaves through an adjustable flow-control device. As the device's check-valve closes, air in the flow section can be adjusted to throttle the cylinder retraction. The flow-controlled air then goes through the valve's port B and leaves at port S through a muffler.

Comparison of Hydraulic & Pneumatic Circuits

Hydraulic Circuits	**Pneumatic Circuits**
1. Working fluid used is oil	1. Working fluid used is air
2. The operation is complicated	2.The operation is simple
3. The operation is quiet	3. The operation is noisy
4. To pressurized the oil, pump is necessary	4. Air compressor is necessary
5. It require return lines, hence the circuit is complicated	5. No return lines are required, hence circuit is simple
6. Speed is limited	6. Very high speed can be possible
7. There is possibility of fire hazards	7. It is safe in volatile atmosphere.

when working with higher temperatures.	
8. Its operating pressure can be lower to very high	8. Its operating pressure is limited to 6 bar
9. In this the system rigidity is good	9. In this system rigidity is poor
10. It has simple maintenance	10. It also has simple maintenance
11. It requires moderate operating cost	11. It requires very low operating cost
12. Overall cost is higher	12. Overall cost is lower
13. It is very much suitable where long strokes are required	13. It is not suitable for long strokes
14. It is suitable for feed movements of machine tools. Stroke control is easy and is very precise	14. It is not suitable for feed movements. Stroke control is easy, but fluctuations cannot be avoidable.
15. Applications: Automatic lathe Drilling machines Grinding machines Shaping machines Crushers Fork lift trucks Dumpers Truck loaders Bulldozers Hydraulic press	15. Applications: Automatic machines for holding, gripping, feeding, bottling, wrapping, packaging etc. Clamping jigs & fixtures Wire feeding For raw material feeding For hoist, Lift, Cranes For furnace operations For power tools For mining boring, shoveling Automatic tillers For press tools Hydraulic Circuits ν A hydraulic circuit is a group of component

Hydraulic Circuits –

- A hydraulic circuit is a group of components arranged in such a way that they will perform a useful task.
- The elements of hydraulic circuit are pumps, actuators, control valves, pipe & pipe fittings, reservoir, accumulator, filter and strainer
- These components are arranged in various ways to obtain a desired output from the circuit. Hydraulic Circuits
- While designing any hydraulic circuit the following points should be considered.

1. Performance of desired function
2. Efficiency of operation
3. Safety of operation
4. How much force is needed?
5. How fast circuit should function (actuating speed)?
6. Control desired – manual, mechanical, electrical, pilot.
7. Input energy source
8. Life of system desired.

Hydraulic power unit

- The hydraulic power unit consist of pump, filter, reservoir, pressure gauge, pressure relief valve, electric motor, shut-off valve, pipe and pipe fittings.
- In this power unit pump is driven by electric motor, oil rushes from reservoir via filter and deliver at higher pressure at its outlet.
- To set maximum pressure in the system, a pressure relief valve is connected which gets open when pressure in the system is above set value.
- The shut-off valve is opened to read the pressure gauge reading. Flow control circuits ν When a constant delivery pump is used to deliver a constant volume of fluid to the circuit, then the speed or feed control should be provided with metering valves.
- To ensure proper feed and speed of an actuator, the flow control valves may be used in the circuits.
- There are following methods to control flow

1. Meter-in control circuit
2. Meter-out control circuit
3. Bleed-off control circuit

Meter-in control circuit

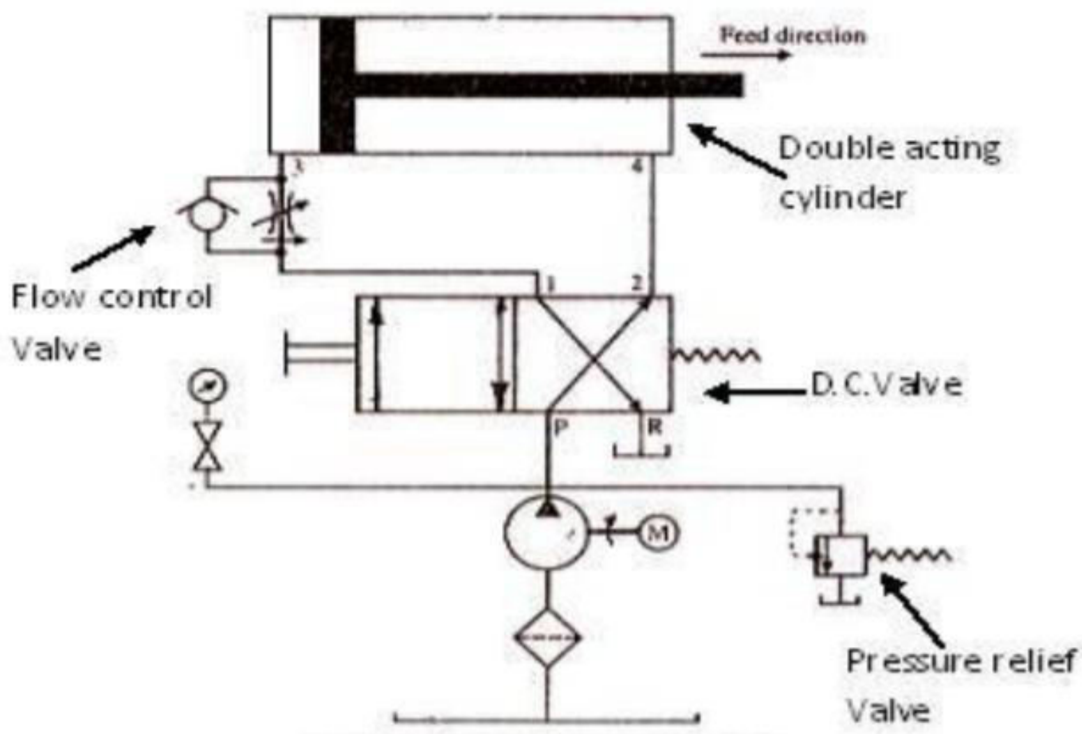


Fig. shows the meter-in circuit.

- In this flow control valve is connected between the D.C valve and blind end of the cylinder.
- Here metered fluid enters the cylinder which controls the speed and feed of the piston.
- When D.C. valve is manually shifted to right side the flow from pump passes through the compensated flow control valve into blind end of cylinder and the exhaust fluid is directed freely to the reservoir.
- When the force on D.C. valve is released, it permits the spool to return due to valve spring and the pump flow is directed to the rod end of the cylinder.

- The fluid from blind end of the cylinder will pass through the integral check valve in the flow control mechanism and the piston can be retracted rapidly to its initial position.
- Flow during retraction is not controlled (i.e. Free flow)
- This method is used when the load characteristics are constant and positive. Hence they are used in surface grinder & milling m/c.
- Also in Shaper planner slotter due to quick return.

Meter-out speed control circuit

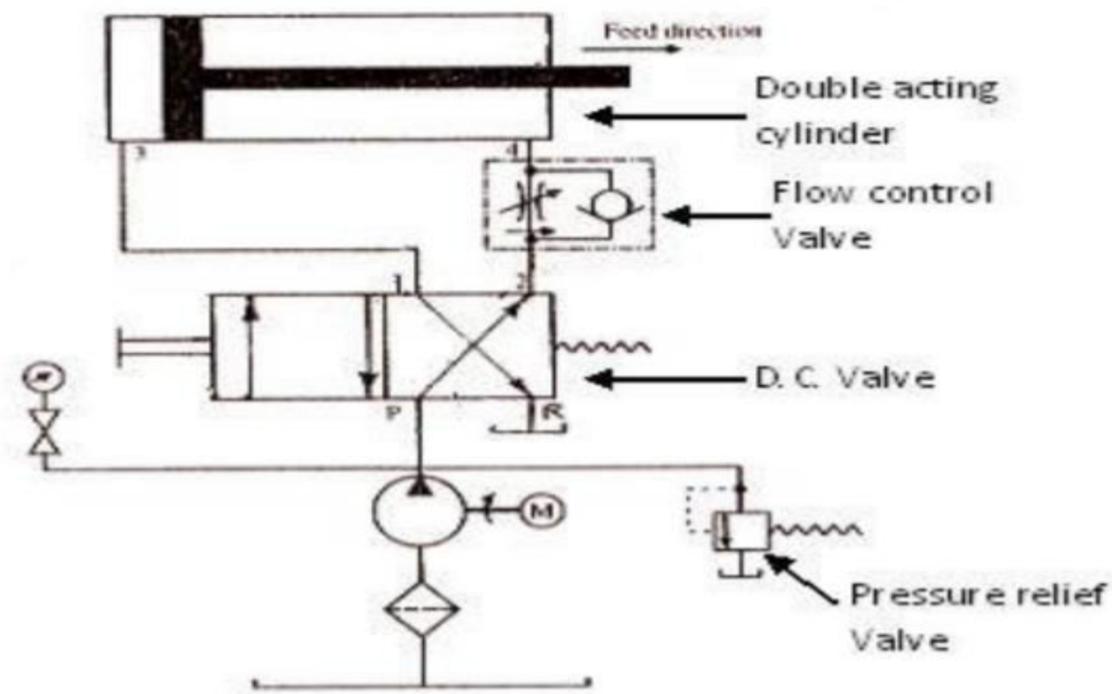


Fig. shows meter-out speed control circuit.

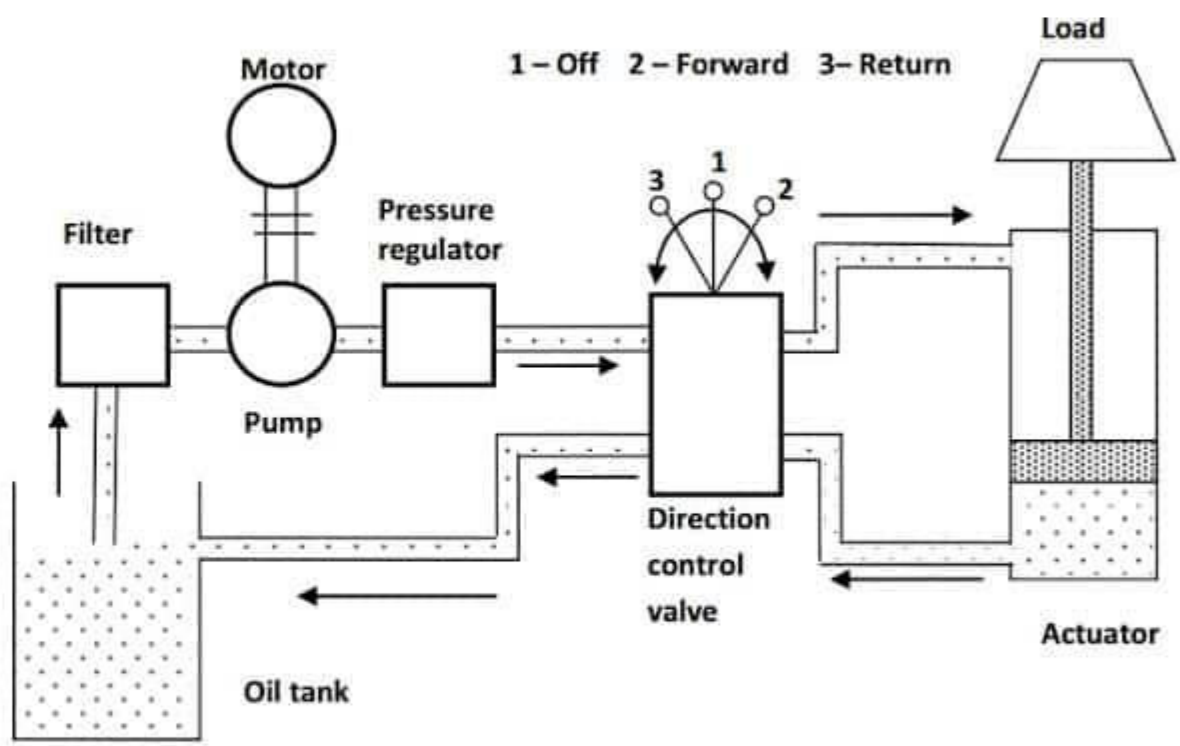
- In this flow control valve is located between D.C. valve and rod end of cylinder in such a way that the fluid is metered as it leaves the cylinder.
- When D.C. valve is manually shifted to right side the flow from pump passes to blind end of cylinder and the exhaust fluid is directed through flow control valve to the reservoir. Due to this the movement of piston is regulated as fluid has restriction on rod end side. Thus piston moves slowly.
- When the force on D.C. valve is released, it permits the spool to return due to valve spring and the pump flow is directed to the rod end of the cylinder through integral check valve in the flow control mechanism.
- The fluid from blind end will flow to D.C. valve as there is no restriction and the piston can be retracted rapidly to its initial position.
- Flow during retraction is not controlled (i.e. Free flow)
- This method is used where free falling load or overhauling load tends to go out of control.
- They are used in operations like drilling, boring, reaming. Shaper planner slotter due to quick return.

Application of Hydraulic circuits

- Hydraulic circuit for Milling M/c
- Hydraulic circuit for Shaper M/c
- Hydraulic circuit for Surface grinder
- Hydraulic circuit for Hydraulic Press ν Hydraulic Power Steering
- Reaction piston type hydraulic steering system
- Hydraulic circuit of Dumpers
- Hydraulic circuit of Excavators

Hydraulic System – Introduction

Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. The figure shows a simple circuit of a hydraulic system with basic components. Hydraulic systems are used for transmission of power through the medium of hydraulic oil. The hydraulic system works on the principle of Pascal's law which says that " the pressure in a fluid at rest is transmitted uniformly in all directions".
The fluid medium used is hydraulic oil, which may be mineral oil or water or combinations. This area is also known as oil hydraulics.



Components of a hydraulic system

Functions of the components

1. **The hydraulic actuator**

- It is a device used to convert fluid power into mechanical power to do useful work. The actuator may be of the linear type (e.g., hydraulic cylinder) or rotary type(e.g., hydraulic motor) to provide linear or rotary motion, respectively.
- The pressurized hydraulic fluid delivered by the hydraulic pump is supplied to the actuators, which converts the energy of the fluid into mechanical energy. This mechanical energy is used to get the work done.
- **TYPES OF ACTUATORS:**
  1. Linear Actuators (Hydraulic cylinders)
  2. Rotary Actuators (Hydraulic motors)
  a. Continuous rotary actuators
  b. Semi rotary actuators
- **Functions Of Actuators :**
  1) To produce motion in one line
  2) To produce continuous rotary motion
  3) To produce rotary or oscillatory motion less than 3600
  4) To apply a force and clamp the job.

2. <u>The hydraulic Pump</u>

- It is used to force the fluid from the reservoir to the rest of the hydraulic circuit by converting mechanical energy into hydraulic energy.
- A pump which is the heart of a hydraulic system converts mechanical energy into hydraulic energy. The mechanical energy is delivered to the pump via prime mover such as the electric motor. Due to the mechanical action the pump creates a partial vacuum at its inlet. This permits atmospheric pressure to force the fluid through the inlet line and into the pump. The pump then pushes the fluid into the hydraulic system.

Importance of Pump :

1. They convert mechanical energy into hydraulic energy.
2. The Volumetric efficiency of the pump is relatively high
3.They have high-performance characteristics under varying speed and pressure requirements
4.Pumps used to generate high pressure in the hydraulic system

3. **<u>Valves</u>**

- Valves are used to control the direction, pressure, and flow rate of a fluid flowing through the circuit.
  Motor 1 – Off 2 – Forward 3– Return 3 2 1 Load Direction control valve Pump Oil tank Filter Actuator Pressure regulator.
- A fluid power system can be broken down into three segments. The power input segment consisting of the prime mover and the pump. The control segment consisting of valves that control the direction, pressure, and flow

rate. The power output segment, consisting of the actuators and the load. This unit is devoted to each of the following categories of control valves.
1. Directional control valves
2. Pressure control valves
3. Flow control valves

- DCVs control the direction of flow in a circuit, which among other things; can control the direction of the actuator. PCVs control the pressure level, which controls the output force of a cylinder or the output torque of a motor. FCVs control the flow rate of the fluid which controls the speed of the actuators.

Different types of valves and their functions :

1. **Pressure relief valves –** Relief valve opens and bypasses fluid when pressure exceeds its setting. These are used mostly in all circuits.
2. **Pressure-Reducing Valve –** This type of valve (which is normally open) is used to maintain reduced pressures in specified locations of hydraulic systems.
3. **Unloading Valves** – high-low pump circuits where two pumps move an actuator at a high speed and low pressure, punching press.
4. **Counterbalance valves –** They are used to prevent a load from accelerating uncontrollably. This situation can occur in vertical cylinders in which the load is a weight. This can damage the load or even the cylinder itself when the load is stopped quickly at the end of the travel.

4. External power supply (motor) is required to drive the pump.

5. Oil Tank or Reservoir:

- This is an oil storage tank in which hydraulic oil is stored. The oil passes through various pipelines and after doing useful work in actuator; the oil returns to the oil tank. In the regions of low temperature, oil heaters are attached to air tanks.
- Reservoir is used to hold the hydraulic liquid, usually hydraulic oil.

6.Pipelines :

- Pipelines (Fluid Conducting elements): It is the functional connection for oil flow in the hydraulic system. The efficiency of oil flow is greatly influenced by the physical characteristics of piping systems.
- There are two pipes:
  a) The pipe which carries pressurized oil is called pressure pipelines
  b) Pipes that carry low pressurized oil or used oil (are called as return pipelines).
- Hoses, pipes, pipe fitting are the parts of the fluid power pipeline.

7. **Filters**

- It is used to remove any foreign particles so as keep the fluid system clean and efficient, as well as avoid damage to the actuator and valves.
- When hydraulic fluids are contaminated, hydraulic systems may get damaged and malfunction due to clogging and internal wear. They require filtration to remove contaminants.
- Filters are classified as
  i. Reservoir filters:
  ii. Line filters
  iii. Off-line filters
  iv. Other cleaning equipment
- **Functions of Filter:**
  1) Take care of the cleanliness of the components.
  2) Reduce the maintenance.
  3) To remove silting.
  4) To increase the system reliability.
  5) To prevent the entrance of solid contaminants to the system.

8. Pressure regulator

- **Pressure regulator** regulates (i.e., maintains) the required level of pressure in the hydraulic fluid.
- The piping is shown in Fig. is of closed-loop type with fluid transferred from the storage tank to one side of the piston and returned from the other side of the piston to the tank. Fluid is drawn from the tank by a pump that produces fluid flow at the required level of pressure. If the fluid pressure exceeds the required level, then the excess fluid returns back to the reservoir and remains there until the pressure acquires the required level.

9. Accumulators

- Accumulators are devices that store hydraulic fluid under pressure. Storing hydraulic fluid under pressure is a way of storing energy for later use. Perhaps the most common application for an accumulator is supplementing the pump flow in a hydraulic system in which a high flow rate is required for a brief period of time.
- **Types of Accumulators ;**
  1. Weight loaded accumulator
  2. Spring-loaded accumulator
  3. Gas-charged accumulator
  4. Piston type
  5. Bladder type
  6. Diaphragm type

10. Hydraulic Power Pack :

- The hydraulic power unit (power supply unit) provides the energy required for the hydraulic installation.
- The main components of power packs are – The reservoir (tank), Drive (electric motor), Hydraulic pump, Pressure relief valve, filter, and cooler.
- The pump or motor unit may be mounted on the tank or separately a packs are usually available in either horizontal or vertical configurations. The basic unit may be piped to the cylinders or actuators through a suitable control valve.
- The hydraulic power packs consist of a reservoir/tank that house the hydraulic fluid, which is the working medium.

Applications of hydraulic systems

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Gear Pumps

Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. They are suitable for a wide range of fluids and offer self-priming performance. Sometimes gear pumps are designed to function as either a motor or a pump. These pump includes helical and herringbone gear sets (instead of spur gears), lobe shaped rotors similar to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps.

Types Of Gear Pumps

Based upon the design, the gear pumps are classified as:
• External gear pumps
• Lobe pumps
• Internal gear pumps
• Gerotor pumps

Generally gear pumps are used to pump:

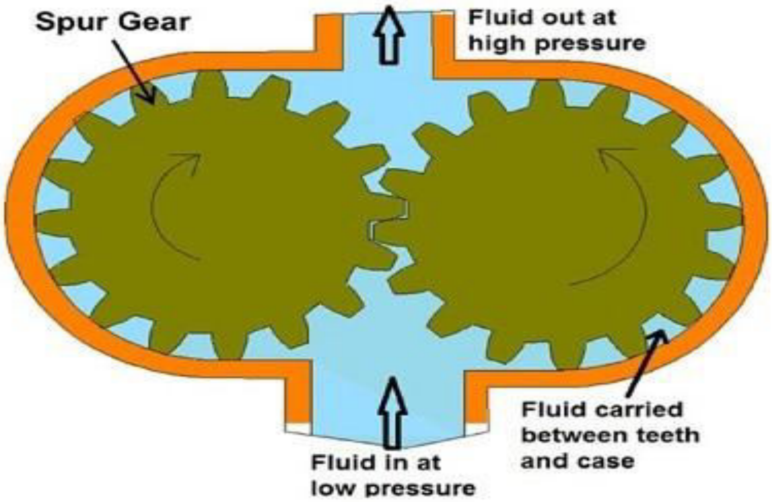
• **Petrochemicals:** Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
• **Chemicals:** Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
• Paint and ink
• Resins and adhesives
• **Pulp and paper:** acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.
• **Food:** Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

External gear pump

The external gear pump consists of externally meshed two gears housed in a pump case as shown in figure . One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh.

How Gear pump Works ?

When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port. The gear pumps are often equipped with the side wear plate to avoid the leakage. The clearance between gear teeth and housing and between side plate and gear face is very important and plays an important role in preventing leakage. In general, the gap distance is less than 10 micrometers. The amount of fluid discharge is determined by the number of gear teeth, the volume of fluid between each pair of teeth and the speed of rotation.



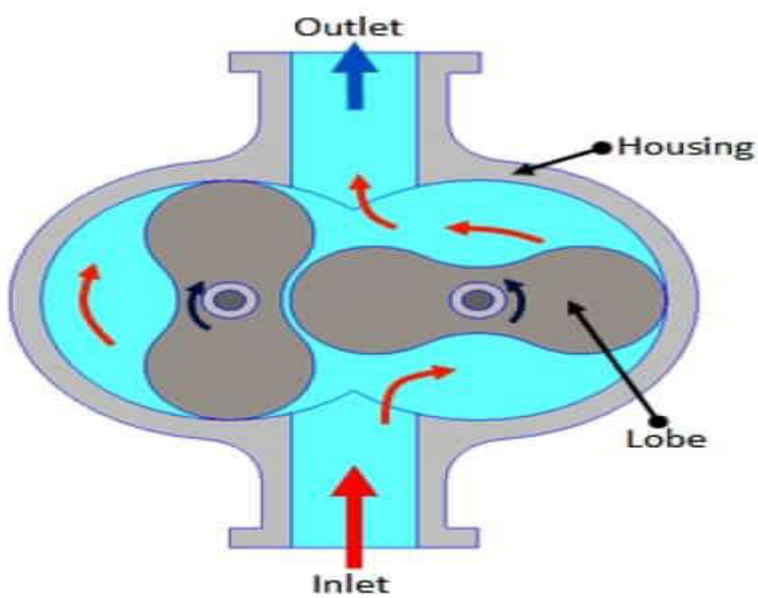
Gear pump

The important drawback of external gear pump is the unbalanced side load on its bearings. It is caused due to high pressure at the outlet and low pressure at the inlet which results in slower speeds and lower pressure ratings in addition to reducing the bearing life.

Gear pumps are most commonly used for the hydraulic fluid power applications and are widely used in chemical installations to pump fluid with a certain viscosity.

Lobe Pumps

Lobe pumps work on the similar principle of working as that of external gear pumps. However in Lobe pumps, the lobes do not make any contact like external gear pump (see Figure).



Lobe pump

Lobe contact is prevented by external timing gears located in the gearbox. Similar to the external gear pump, the lobes rotate to create expanding volume at the inlet. Now, the fluid flows into the cavity and is trapped by the lobes. Fluid travels around the interior of casing in the pockets between the lobes and the casing. Finally, the meshing of the lobes forces liquid to pass through the outlet port. The bearings are placed out of the pumped liquid. Therefore the pressure is limited by the bearing location and shaft deflection.

Because of superb sanitary qualities, high efficiency, reliability, corrosion resistance and good clean-in-place and steam-in-place (CIP/SIP) characteristics, Lobe pumps are widely used in industries such as pulp and paper, chemical, food, beverage, pharmaceutical and biotechnology etc. These pumps can handle solids (e.g., cherries and olives), slurries, pastes, and a variety of liquids. A gentle pumping action minimizes product degradation. They also offer continuous and intermittent reversible flows. Flow is relatively independent of changes in process pressure and therefore, the output is constant and continuous.

Lobe pumps are frequently used in food applications because they handle solids without damaging the product. Large sized particles can be pumped much effectively than in other positive displacement types. As the lobes do not make any direct contact therefore, the clearance is not as close as in other Positive displacement pumps. This specific design of pump makes it suitable to handle low viscosity fluids with diminished performance.

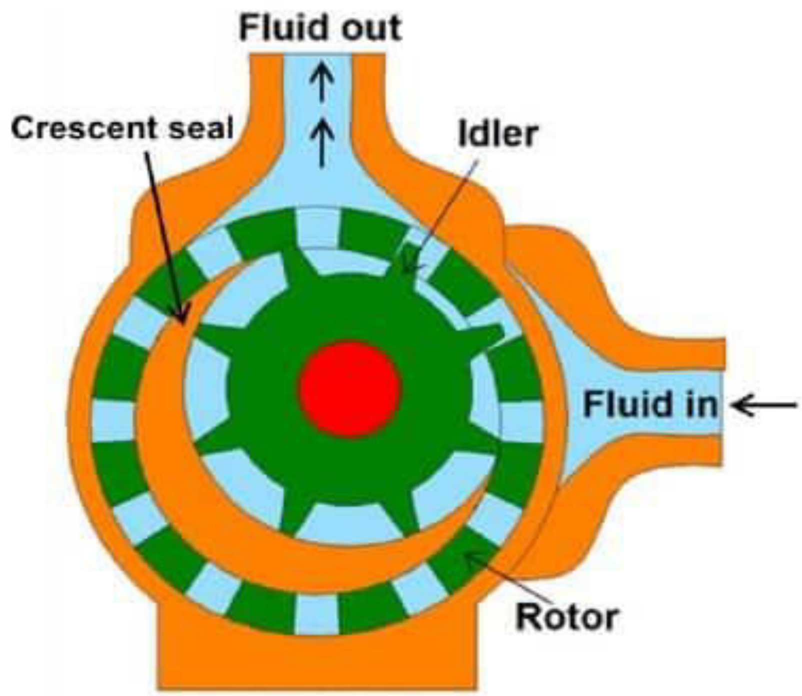
Loading characteristics are not as good as other designs, and suction ability is low. High-viscosity liquids require reduced speeds to achieve satisfactory performance. The reduction in speed can be 25% or more in case of high viscosity fluid.

Internal Gear Pump :

Internal gear pumps are exceptionally versatile. They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature. This is non-pulsing, self-priming and can run dry for short periods. It is a variation of the basic gear pump.

It comprises of an internal gear, a regular spur gear, a crescent-shaped seal and an external housing. The schematic of internal gear pump is shown in figure .Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth. Liquid travels through the pump between the teeth and crescent. Crescent divides the liquid and acts as a seal between the suction and discharge ports. When the teeth mesh on the side opposite to the crescent seal, the fluid is forced out through the discharge port of the pump. This clearance between gears can be adjusted to accommodate high temperature, to handle high viscosity fluids and to accommodate the wear. These pumps are bi-rotational so that they can be used to load and unload the vessels. As these pumps have only two moving parts and one stuffing box, therefore they are reliable, simple to operate and easy to maintain. However, these pumps are not suitable for high speed and high pressure applications. Only one bearing is used in the pump therefore overhung load on shaft bearing reduces the life of the bearing.

internal gear pump -types of gear pump



Internal gear pump

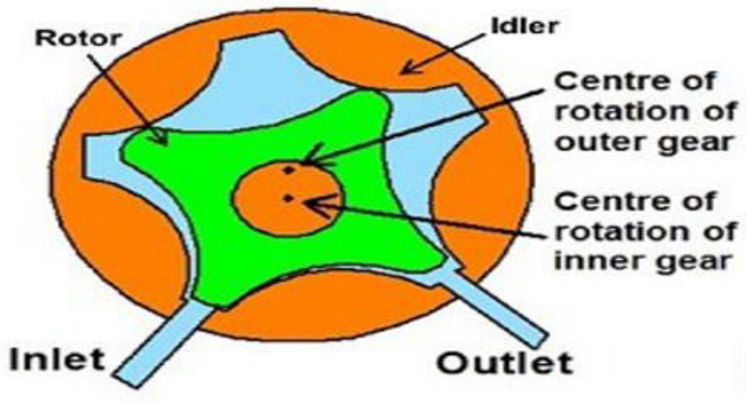
Applications

Some common internal gear pump applications are:

- All varieties of fuel oil and lube oil
- Resins and Polymers
- Alcohols and solvents
- Asphalt, Bitumen, and Tar
- Polyurethane foam (Isocyanate and polyol)
- Food products such as corn syrup, chocolate, and peanut butter
- Paint, inks, and pigments
- Soaps and surfactants
- Glycol

Gerotor Pump :

Gerotor is a positive displacement pump. The name Gerotor is derived from "Generated Rotor". At the most basic level, a Gerotor is essentially one that is moved via fluid power. Originally this fluid was water, today the wider use is in hydraulic devices. The schematic of Gerotor pump is shown in figure 5.2.5. Gerotor pump is an internal gear pump without the crescent. It consists of two rotors viz. inner and outer rotor. The inner rotor has N teeth, and the outer rotor has N+1 teeth. The inner rotor is located off-center and both rotors rotate. The geometry of the two rotors partitions the volume between them into N different dynamically-changing volumes. During the rotation, volume of each partition changes continuously. Therefore, any given volume first increases, and then decreases. An increase in volume creates vacuum. This vacuum creates suction, and thus, this part of the cycle sucks the fluid. As the volume decreases, compression occurs. During this compression period, fluids can be pumped, or compressed (if they are gaseous fluids).



Gerotor Pump

The close tolerance between the gears acts as a seal between the suction and discharge ports. Rotor and idler teeth mesh completely to form a seal equidistant from the discharge and suction ports. This seal forces the liquid out of the discharge port. The flow output is uniform and constant at the outlets.
The important advantages of the pumps are high speed operation, constant discharge in all pressure conditions, bidirectional operation, less sound in running condition and less maintenance due to only two moving parts and one stuffing box etc. However, the pump is having some limitations such as medium pressure operating range, clearance is fixed, solids can't be pumped and overhung load on the shaft bearing etc.

Applications

Gerotors are widely used in industries and are produced in variety of shapes and sizes by a number of different methods. These pumps are primarily suitable for low pressure applications such as lubrication systems or hot oil filtration systems, but can also be found in low to moderate pressure hydraulic applications. However common applications are as follows:

- Light fuel oils
- Lube oil
- Cooking oils
- Hydraulic fluid

Advantages and disadvantages of gear pumps

The advantages are as follows:

1.They are self-priming.
2.They give constant delivery for a given speed.
3. They are compact and light in weight.
4. Volumetric efficiency is high.

The disadvantages are as follows:

1. The liquid to be pumped must be clean, otherwise it will damage pump.
2. Variable speed drives are required to change the delivery.
3. If they run dry, parts can be damaged because the fluid to be pumped is used as lubricant.