



GOVERNMENT POLYTECHNIC, BHADRAK

Hydraulic Machines & Industrial Fluid Power (Th- 03)

(As per the 2019-20 syllabus of the SCTE&VT,
Bhubaneswar, Odisha)



Fifth Semester

Mechanical Engg.

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Hydraulic Machine & Industrial Fluid power

Topic wise Distribution periods

Sl No.	Topics	No. of periods as per Syllabus	No. of period actually needed	Expected mark	
1	Hydraulic Turbines	10	11	07	12
2	Centrifugal Pumps	05	05	06	15
3	Reciprocating pumps	05	05	07	13
4	Pneumatic Control System	20	21		20
5	Hydraulic control System	20	21		20
	Total	60	63	20	80

CHAPTER 01

HYDRAULIC TURBINE

INTRODUCTION: -

Hydraulic machines are defined as those machines which convert either hydraulic energy into mechanical energy or mechanical energy into hydraulic energy. The hydraulic machine which convert hydraulic energy into mechanical energy is called turbine and the hydraulic machine which convert mechanical energy into hydraulic energy is called pump.

1.1HYDRAULIC TURBINES: -

- The hydraulic machine which convert hydraulic energy into mechanical energy is called turbine. This mechanical energy is used in running an electric generator which is directly coupled to the turbine shaft.
- Thus, mechanical energy is converted into electrical energy the electric power which is obtained from the hydraulic energy is known as hydro-electric power.

CLASSIFICATION OF TURBINE

Turbines can be classified on the basis of:

1. According to the energy available at the inlet-

- (a) Impulse turbine
- (b) Reaction turbine

2. According to the direction of flow through the runner

- a) Tangential flow turbines
- b) Radial flow turbines
- c) Axial flow turbine
- d) Mixed flow turbine

3. According to the head available at the

- a) High head turbine
- b) Medium head turbine
- c) Low head turbine

4. According to the specific speed of the turbine

- a) Low specific speed turbine
- b) Medium specific speed turbine

c) High specific speed turbine

- If at the inlet of the turbine the energy available is only kinetic energy then it is called an impulse turbine. If at the inlet of the turbine both kinetic as well as pressure energy are available then it is called reaction turbine.
- If water flows along the tangent of the runner, then it is called tangential flow turbine. If water flows along radial direction, then it is called radial flow turbine. If the water flows from outward to inward radially the turbine is called inward radial flow turbine. If water flows from inward to outward the turbine is called outward radial flow turbine.
- If the water flows through the runner along parallel to the axis of rotation of the runner, then the turbine is called axial flow turbine.
- If the water flows through the runner in radial direction but leaves in axial direction then the turbine is called mixed flow turbine.

IMPULSE TURBINE

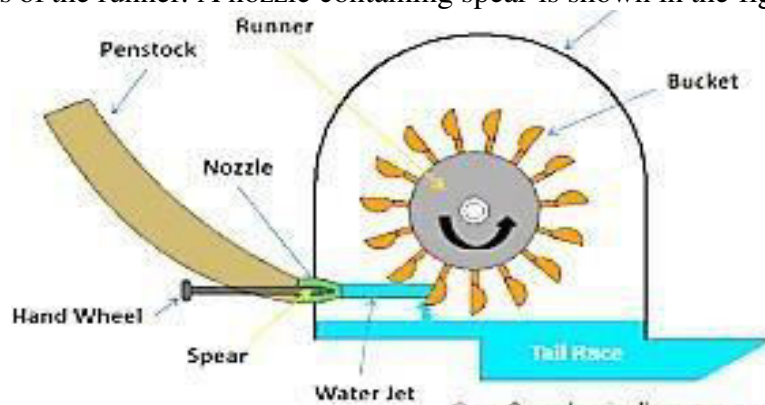
- Pelton wheel is a tangential flow Impulse Turbine. The energy available at the inlet of the Pelton turbine is only kinetic energy. The pressure at the inlet and outlet of the turbine is atmospheric Pressure. This type of turbine is used for high head.

Main Parts of Pelton wheel

The various parts of the Pelton turbine are

1. Nozzle and Flow Regulating Arrangement (Spear)

- Nozzle is used to increase the kinetic energy of the water that is going to strike the buckets or vanes attached to the runner.
- The quantity of water that strikes the buckets is controlled by spear. The spear is installed inside the nozzle and regulates the flow of water that is going to strike on the vanes of the runner. A nozzle containing spear is shown in the figure given below.



- The spear is a conical needle present in the nozzle. It is operated by a hand wheel or automatically in an axial direction.
- When the spear is moving backward the rate of flow of water increases and when it is pushed forward the rate of flow of water.

2. Runner and Buckets

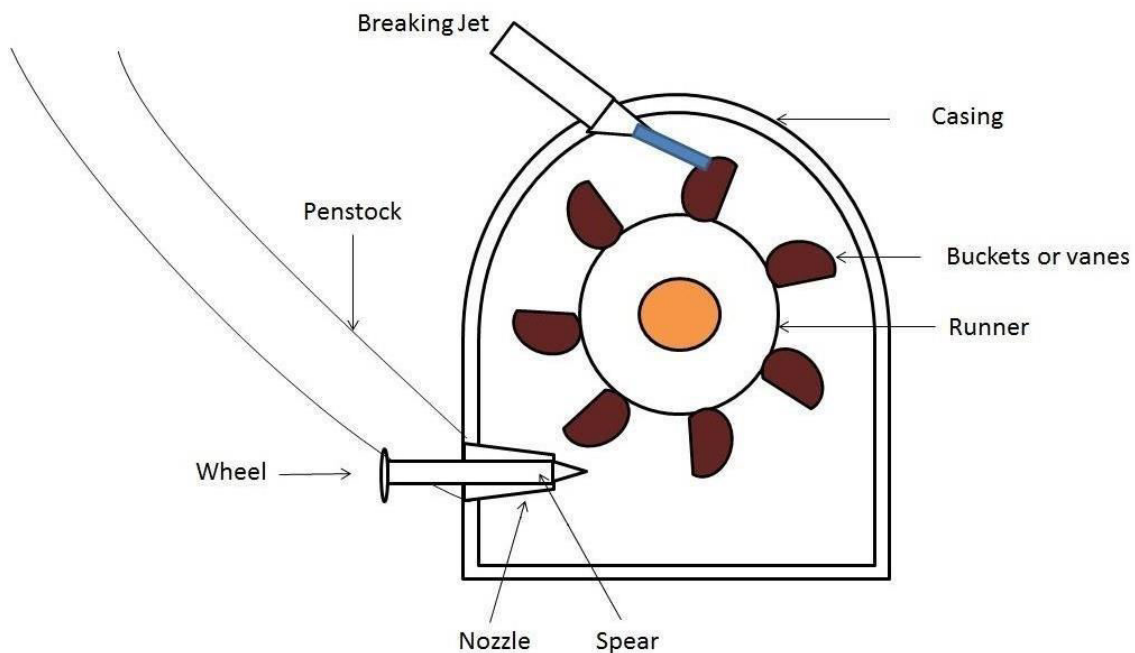
- Runner is a rotating part of the turbine. It is a circular disc on the periphery of which a number of buckets evenly spaced are fixed.
- The buckets are made by two hemispherical bowl joined together. Each bucket has a wall in between two hemispherical bowl called splitter.

3. Casing:

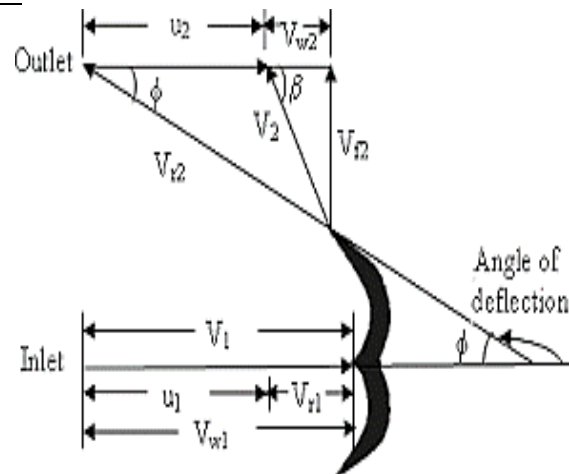
- The outer covering of this turbine is called casing. The Pelton turbine with the casing is shown in the figure given below.
- It prevents the splashing of the water and helps to discharge the water to the tail race. It also acts as a safeguard in the case of any accident occurs.
- Cast iron or fabricated steel plates are used to make the casing of the Pelton Turbine.

4. Breaking jet:

- **Breaking jet** When the jet of water is completely closed by pushing the spear in forward direction than the amount of water striking the runner becomes zero. But still the runner keeps moving due to the inertia of the runner.
- In order to stop the runner in the shortest possible time a small nozzle is provided which directs the jet of water at the back of the vanes. This jet of water used to stop the runner of the turbine is called breaking jet.



VELOCITY DIAGRAM, WORK DONE AND EFFICIENCIES OF IMPULSE TURBINE



Let V = Velocity of the jet

U = Velocity of the vane (blade) at the impact point

$$U = \pi DN / 60$$

where D = Diameter of the wheel corresponding to the impact point

d = Pitch circle diameter.

At inlet the shape of the vane is such that the direction of motion of the jet and the vane is the same hence $\alpha = 0$ and $\theta = 0$

Relative velocity at inlet $V_{r1} = V_1 - U_1$

Whirl velocity $V_{w1} = V_1$

From the velocity triangle at outlet $V_{r1} = V_{r1}$, $V_{w2} = V_{r2} \cos \phi - U_2$

The force exerted by the jet of water in the direction of motion

$$F_x = \rho a V_1 (V_{w1} + V_{w2})$$

$$\text{Work done by the jet} = \rho a V_1 (V_{w1} + V_{w2}) U \text{ Nm/s}$$

$$\text{Power given to the runner by the jet} = \rho a V_1 (V_{w1} + V_{w2}) U / 1000 \text{ KW}$$

Work done per second per unit

weight of water striking/sec =

$$\rho a V_1 (V_{w1} + V_{w2}) U / \text{weight of water striking per second}$$

$$= \rho a V_1 (V_{w1} + V_{w2}) U / \rho a V_1 g$$

Hydraulic efficiency

$\eta_h = \text{work done per second} / \text{K. E of jet per second}$

$$= \rho a V_1 (V_{w1} + V_{w2}) U / (1/2 \rho a V_1 \times V_1)$$

$$= 2(V_{w1} + V_{w2}) U / V_1^2$$

$$\text{Maximum efficiency} = (1 + \cos \phi) / 2$$

Points To Be Remembered For Pelton Wheel

- (1) The velocity of jet at inlet is given by, $V_1 = C_v \sqrt{2 g H}$
- (2) Velocity of wheel (U) is given by $U = \theta \sqrt{2 g H}$
- (3) The angle of deflection of the jet is 165° when it is not given

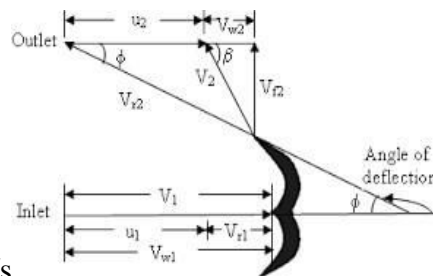
- (4) The mean diameter or pitch diameter of the Pelton wheel D is $U = \pi D N / 60$
- (5) Jet ratio: It is defined as the ratio of pitch diameter and Pelton wheel diameter. it is denoted by m .
 $M = D/d$
- (6) Number of bucket on a runner $Z = 1.5 + D/2d$
- (7) Number of jet -it is obtained by dividing the total rate of flow through the turbine by the rate of flow of water through a single jet.

PROBLEM - 01

A Pelton wheel has a mean bucket speed of 10 meters per second with a jet of water flowing at the rate of 700 litres/s under a head of 30 meters. The buckets deflect the jet through an angle of 160° . Calculate the power given by the runner and the hydraulic efficiency of the turbine. Assume co-efficient of velocity as 0.98.

Solution given date

Speed of bucket $U = U_1 = U_2 = 10 \text{ m/s}$



Discharge (Q) = 700 litres/s = $0.007 \text{ m}^3/\text{s}$

Angle of deflection = 160°

Angle(ϕ) = $180 - 160 = 20$

Co-efficient of velocity $C_v = 0.98$

The velocity of jet $V_1 = C_v \sqrt{2 g H}$

$$= 0.98 \times \sqrt{2 \times 9.81 \times 30} = 23.77 \text{ m/s}$$

$$V_{r1} = V_1 - U_1 = 23.77 - 10 = 13.77 \text{ m/s}$$

$$V_{w1} = V_1 = 23.77 \text{ m/s}$$

From the outlet triangle $V_{r2} = V_{r1} = 13.77 \text{ m/s}$

$$V_{w2} = V_{r2} \cos \phi - U_2 = 2.94 \text{ m/s}$$

Work done by the jet = $\rho a V_1 (V_{w1} + V_{w2}) U$

$$= 1000 \times 23.77 (23.77 + 2.94) \times 10$$

$$= 186970 \text{ Nm/s (ans)}$$

power = $186970/1000 = 186.97 \text{ kw (ans)}$

Hydraulic efficiency

$\eta_h = \text{work done per second} / \text{K. E of jet per second}$

$$= 2(V_{w1} + V_{w2}) U / V_1^2$$

$$= 2 \times (23.77 + 2.94) \times 10 / 23.77^2$$

$$= 0.9454 = 94.54\% \text{ (ans)}$$

REACTION TURBINE: -

➤ If the energy available at the inlet of the turbine is both kinetic as well as pressure energy then the turbine is called reaction turbine.

➤ It is up two types-

- (1) Francis Turbine

(2) Kaplan turbine

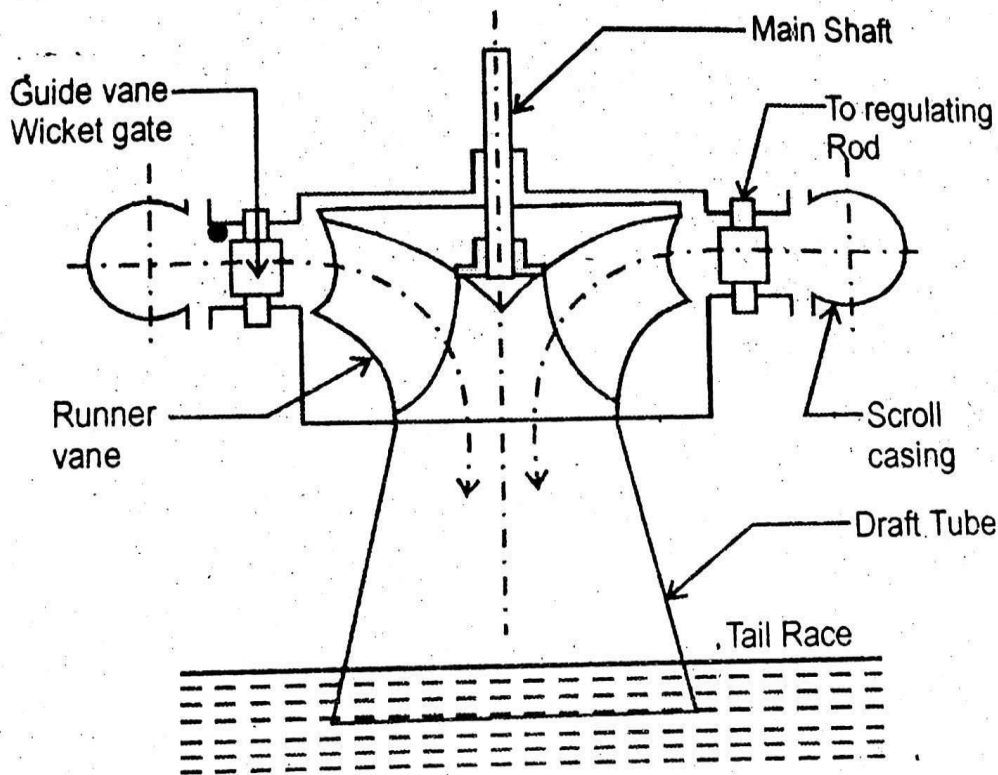
FRANCIS TURBINE

- The Francis turbine is a mixed flow reaction turbine. This turbine is used for medium heads with medium discharge. Water enters the runner and flows towards the centre of the wheel in the radial direction and leaves parallel to the axis of the turbine.

Parts of Francis Turbine

Francis turbine consists mainly of the following parts

- a) Spiral or scroll casing –
- b) Guide mechanism –
- c) Runner and turbine main Shaft:
- d) Draft tube:
- e) Penstock

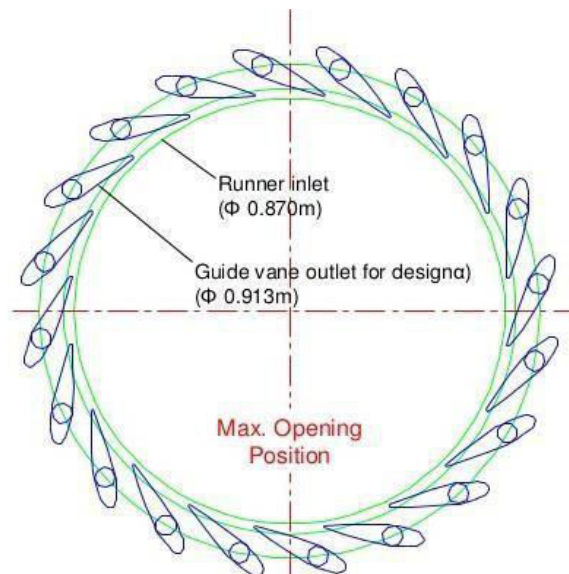


Spiral casing or scroll Casing:

- 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.

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.



Guide vanes

- 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 iron,

Turbine Main Shaft:

- Runner is a circular wheel on which a series of radial curved vanes are fixed. The surface of the vanes is made very smooth. The radial curved vanes are so shaped that the water enters and leaves the runner without shocks.

Draft Tube:

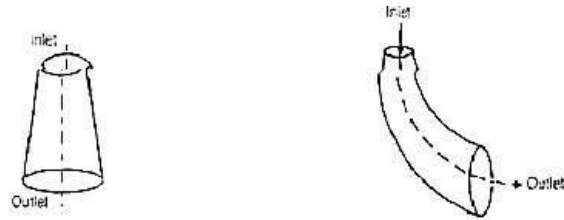
- The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. The water at the exit cannot be directly discharged to the tailrace. A tube or pipe of the gradually increasing area is used for discharging water from the exit of the turbine to the tailrace. This tube of increasing area is called the draft tube.
- The water after doing work on the runner passes on to the tail race through a tube called a draft tube

Types of draft tube:

- I. Conical draft tube
- ii. Simple elbow draft tube

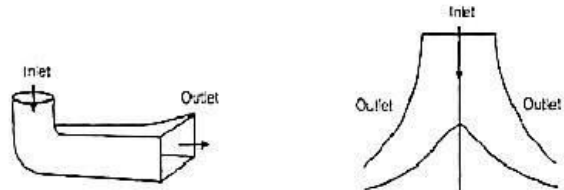
iii. Moody spreading draft tube

iv. Elbow draft tube with circular cross-section at inlet and rectangular at outlet.



Conical or Divergent Draft Tube

Simple Elbow Draft Tube



Elbow Tube Having
Circular Cross-section
at inlet and rectangular at Outlet

Hydracone or Moody
Spreading Draft Tube

Velocity triangle, work done and efficiencies of Francis turbine

Let,

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

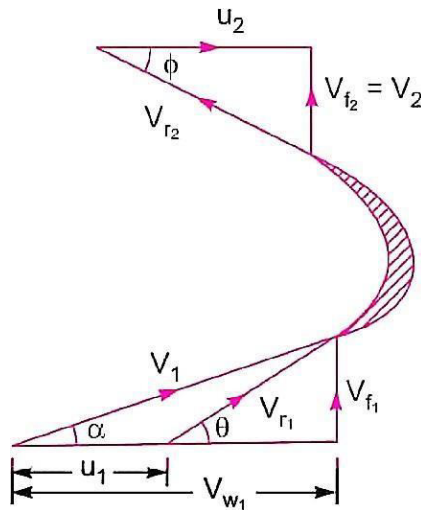
V_{r2} = Relative Velocity at the outlet of the runner

ϕ = Vane angle at the exit.

θ = Vane angle at inlet

β = 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. $\beta = 90^\circ$



Let V = Velocity of the jet

The work done per second on the runner by water is given by

$$= \rho a V_1 [V_{w1} U_1]$$

$$= \rho Q [V_{w1} U_1]$$

Tangential velocity of wheel at inlet, $U_1 = \pi D_1 N / 60$

Tangential velocity of wheel at outlet, $U_2 = \pi D_2 N / 60$

The work done per second per unit weight of water striking per second to the runner.

= work done per second / weight of water striking per second

$$= 1/g [V_{w1} U_1]$$

Hydraulic efficiency $\eta_h = R.P/W.P$

$$= V_{w1} U_1 / g H$$

Ratio of width of wheel to its diameter $n = B_1 / D_1$

Flow ratio $(\phi) = V_{f1} / \sqrt{2 g H}$

Speed ratio $= U_1 / \sqrt{2 g H}$

Problem - 02

A reaction turbine works at 450 R.P.M. under a head of 120 meters. Its diameter at inlet is 120cm and flow area is 0.4 m^2 . The angle made by the absolute and relative velocities at inlet are 20 and 60 respectively with the tangential velocity.

Determine-

1. The volume flow rate
2. The power developed
3. Hydraulic efficiency

Assume whirl at outlet to be zero.

Solution- given

Speed of the turbine, $(N) = 450 \text{ R.P.M.}$

Head, $H = 120 \text{ m}$

Diameter at inlet $D_1 = 120 \text{ cm} = 1.2 \text{ m}$

Flow area, $\pi D_1 B_1 = 0.4 \text{ m}^2$

$\alpha = 20$

$\theta = 60$

$V_{w2} = 0$

Tangential velocity of wheel at inlet, $U_1 = \pi D_1 N / 60$

$$= \pi \times 1.2 \times 450 / 60$$

$$= 28.27 \text{ m/s}$$

From velocity triangle at inlet, $\tan \alpha = V_{f1} / V_{w1} = 0.364$

$$V_{f1} = 0.364 \times V_{w1}$$

$$\tan \theta = V_{f1} / (V_{w1} - U_1)$$

$$V_{w1} = 35.79 \text{ m/s}$$

$$V_{f1} = 13.027 \text{ m/s}$$

Volume flow rate, $Q = \pi D_1 B_1 V_{f1} = 0.4 \times 13.027 = 5.211 \text{ m}^3/\text{s}$

Work-done per second, $= \rho Q [V_{w1} U_1]$

$$= 1000 \times 5.211 [35.79 \times 28.27]$$

$$= 5272402 \text{ Nm/s}$$

Power developed, $p = \text{work done} / 1000$

$$= 5272402 / 1000 = 5272.402 \text{ kw}$$

Hydraulic efficiency, $\eta_h = V_{w1} U_1 / g H$

$$= 35.79 \times 28.27 / 9.81 \times 120 = 85.95\%$$

KAPLAN TURBINE: -

- Kaplan Turbine works on the principle of axial flow reaction. In axial flow turbines, the water flows through the runner along the direction parallel to the axis of rotation of the runner. The water at the inlet of the turbine possesses both kinetic energy as well as pressure energy.
- For axial flow reaction turbine, the shaft of the turbine is vertical. The lower end of the shaft is made larger which is known as hub or boss. The vanes are fixed to the hub acts as a runner for axial flow reaction turbine.
- Following are the important type of axial flow turbine-
 1. Propeller turbine
 2. Kaplan turbine
- When the vanes are fixed to the hub and they are not adjustable the turbine is called propeller turbine. And when the vanes are adjustable the turbine is known as Kaplan turbine.

MAIN COMPONENTS OF KAPLAN TURBINE

The main parts of Kaplan Turbine are,

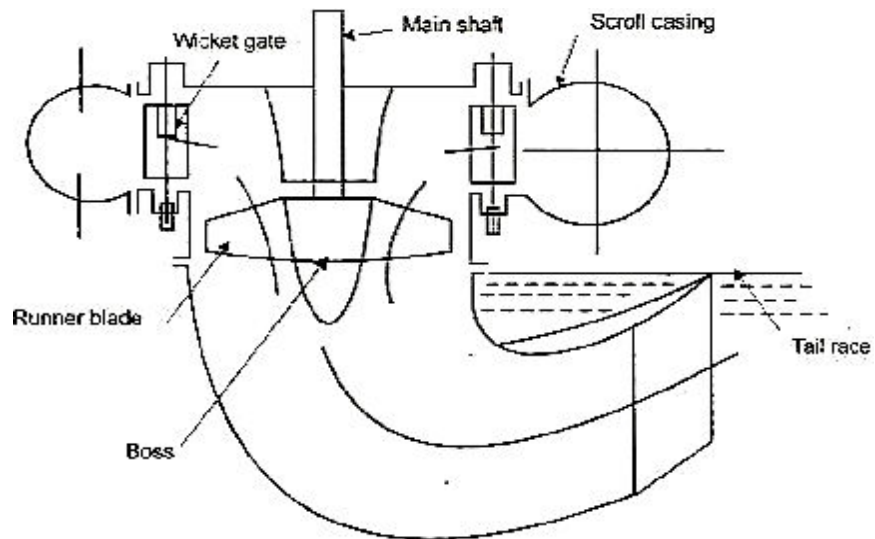
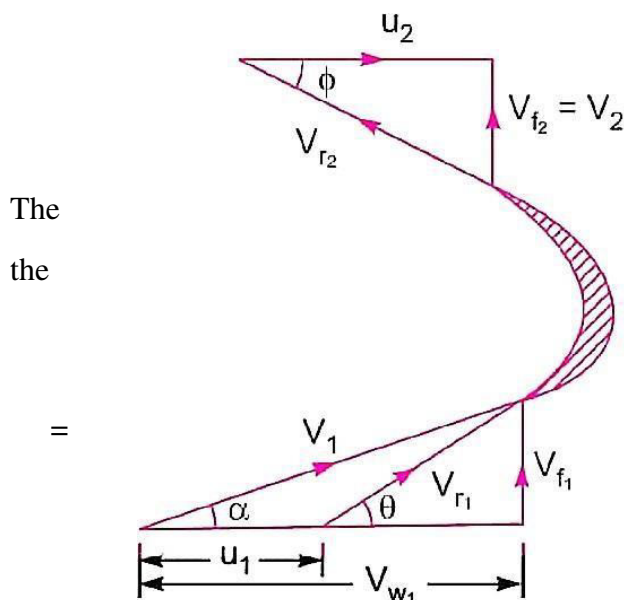


Figure: Kaplan turbine

1. Scroll Casing
2. Guide Vane Mechanism
3. RUNNER BLADES
4. DRAFT TUBE



VELOCITY DIAGRAM, WORKDONE AND EFFICIENCIES OF KAPLAN TURBINE



The
the

=

work done per second on the runner by
water is given by = $\rho a V_1 [V_{w1} U_1 +$
 $V_{w2} U_2]$

$$= \rho Q [V_{w1} U_1 + V_{w2} U_2]$$

Tangential velocity of wheel at inlet,

$$U_1 = \pi D_1 N / 60$$

Tangential velocity of wheel at outlet, $U_2 = \pi D_2 N / 60$

The work done per second per unit weight of water striking per second to the runner.

= work done per second / weight of water striking per second

$$= 1/g [V_{w1} U_1]$$

Hydraulic efficiency $\eta_h = R.P/W.P.$

$$= V_{w1} U_1 / g H$$

Ratio of width of wheel to its diameter $n = B_1 / D_1$

Flow ratio $(\phi) = V_{f1} / \sqrt{2 g H}$

Speed ratio = $U_1 / \sqrt{2 g H}$

Discharge of the turbine

$$Q = \pi D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$$

Problem

an inward flow reaction turbine has external and internal diameters as 1m and 0.5 m respectively. the velocity of flow through the runner is constant and is equal to 1.5 m/s. determine-

1. Discharge through the runner
2. width of the turbine at outlet if the width of the turbine at inlet is = 200 mm

solution

$$D_1 = 1\text{ m}$$

$$D_2 = 0.5\text{ m}$$

$$V_{f1} = V_{f2} = 1.5\text{ m/s}$$

$$B_1 = 200\text{ mm} = 0.2\text{ m}$$

$$\text{Discharge (Q)} = \pi D_1 B_1 V_{f1} = \pi \times 1 \times 0.2 \times 1.5 = 0.9425\text{ m}^3/\text{s}$$

$$\text{Also, } \pi D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$$

$$B_2 = D_1 B_1 / D_2 = 0.4\text{ m} = 400\text{ mm (ans)}$$

Differences between Impulse and Reaction Turbines:

Impulse Turbine	Reaction Turbine
In impulse turbine at the inlet of the turbine only kinetic energy is available.	In reaction turbine kinetic as well as pressure energy is available.
Air tight casing is not necessary. Casing has no hydraulic function.	The runner is enclosed with an air tight casing.
Here breaking jet is required.	It does not require any breaking jet.
It uses nozzle to convert pressure energy into kinetic energy.	It uses draft tube to convert kinetic energy into pressure energy.
The turbine does not run full and air has a free access to the bucket.	Water completely fills at the passage between the blades while flowing between the inlet and outlet
The turbine is always installed above the tail race	It may be installed above or below the tail race.

SHORT QUESTIONS WITH ANSWERS

- 1) Define turbine? 2018(S)
Ans – Turbine is a hydraulic machine which convert hydraulic energy into mechanical energy.
- 2) Why casing is provided in the Pelton wheel? 2019(S)
Ans- casing is used to prevent splashing of water to the atmosphere and discharge the water to the tail race.
- 3) Give one example from each of the following water turbine-
 - (i) Impulse turbine
 - (ii) Reaction turbineAns- Example of impulse turbine-Pelton wheel.
Example of reaction turbine – Kaplan turbine.
- 4) What is surge tank? 2018 (s)
Ans – a surge tank is a standpipe or storage reservoir which is situated in between dam and turbine and connected to the penstock is used to absorb sudden rises of pressure as well as to quickly provide extra water during a brief drop in pressure.

LONG QUESTIONS

- 1) Classify hydraulic turbine? 2018(s)
- 2) A Pelton wheel working under a head of 500m produces 13000 kw at 430 R.P.M. if the efficiency of wheel is 50% determine-
 - (i) Discharge of the turbine
 - (ii) Diameter of the wheel
 - (iii) Diameter of the nozzleTake $C_v = 0.98$ 2018(S)
- 3) A Pelton wheel has a mean bucket speed of 10m/s with a jet of water flowing at rate of 800 litres/s under a head of 40 metres. The bucket deflect the jet through an angle of 160° . Calculate the power given by the water to the runner and hydraulic efficiency of the turbine. Assume co-efficient of velocity as 0.98? 2019(S)
- 4) Draw the layout of a hydro-electric power plant and mention its features? 2019 (S)
- 5) What is hydraulic turbine and classify it? 2019(S)

CHAPTER -02

CENTRIFUGAL PUMPS

INTRODUCTION: -

The hydraulic machine which convert mechanical energy into hydraulic energy is called pump. The hydraulic energy in the form of pressure energy. If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called centrifugal pump.

The centrifugal pump acts as a reversed of an inward radial flow reaction turbine. This means that the flow in centrifugal pump is in the radial outward direction.

CONSTRUCTION AND WORKING PRINCIPLE OF A CENTRIFUGAL PUMP:

MAIN PARTS OF A CENTRIFUGAL PUMP: -

Parts of centrifugal pump are different types. But following are the main parts of the pump as discussed below:

- 1) Impeller
- 2) Casing
- 3) Suction pipes with a foot valve and a strainer
- 4) Delivery pipes

1) Impeller: -

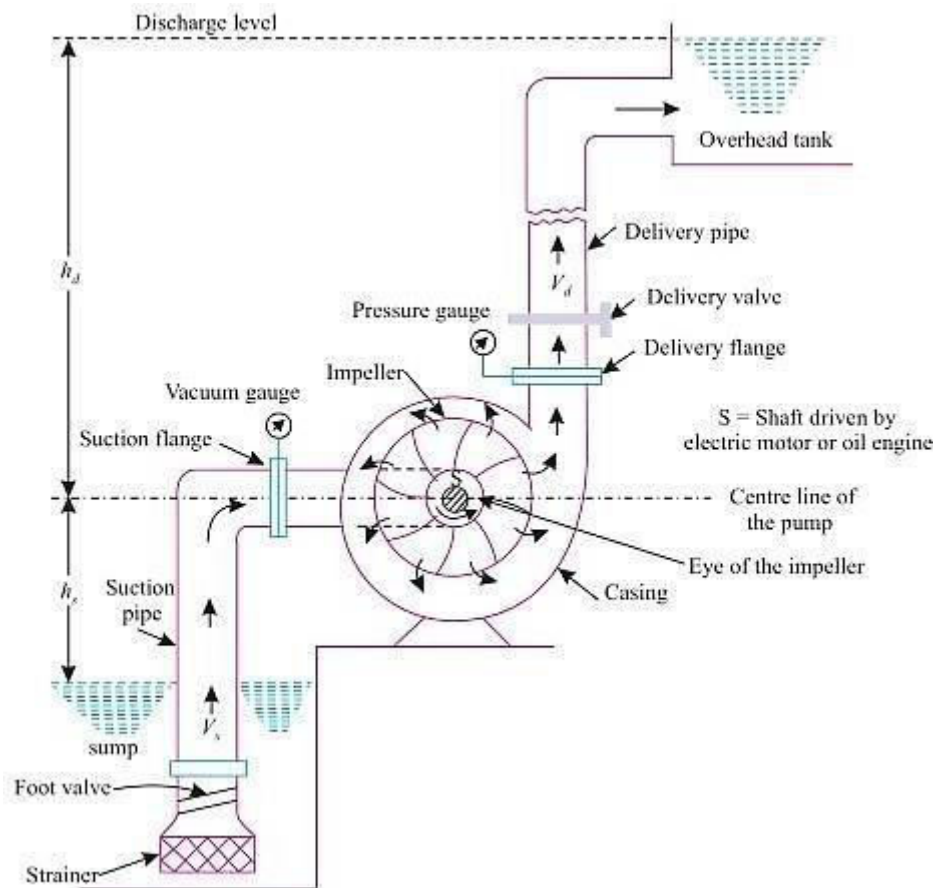
The rotating part of a centrifugal pump is impeller. It consists of a series of backward curved vanes. The impeller is mounted on a shaft which is connected to a shaft of an electric motor

2) Casing

The casing of a centrifugal pump is similar to the casing of a reaction turbine. It is an air tight passage surrounding the impeller and is designed in such a way that the kinetic energy of water discharged at the outlet of the impeller is converted into pressure energy before water leaves the casing and enters the delivery pipe.

The following three types of the casing are commonly adopted:

- (a) Volute casing
- (b) Vortex casing
- (c) Casing with guide blades



(a) The Volute Chamber:

The volute chamber is a spiral casing surrounding the wheel which is also called the impeller. The water which leaves the vanes is directed to move in the volute chamber circumferentially. The area of the volute chamber increases gradually and hence, the velocity gets decreased accompanied by corresponding increase of pressure. As the water reaches the delivery pipe, a considerable part of kinetic energy is converted into pressure energy.

b) Vortex or Whirlpool Chamber:

This is an improvement over the ordinary volute chamber. In this case, the impeller is surrounded by a chamber by combining a circular chamber and a spiral chamber. In this arrangement the efficiency is increased considerable

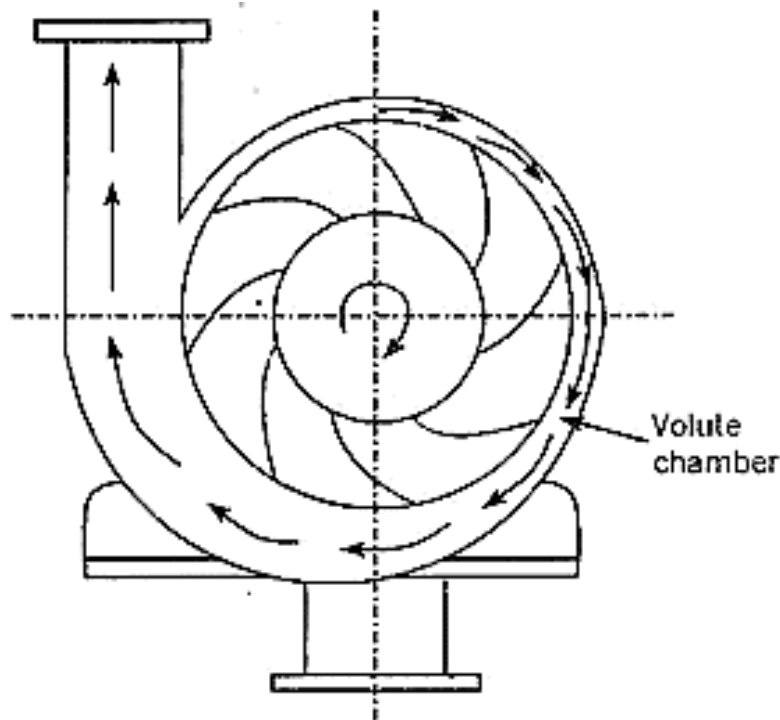
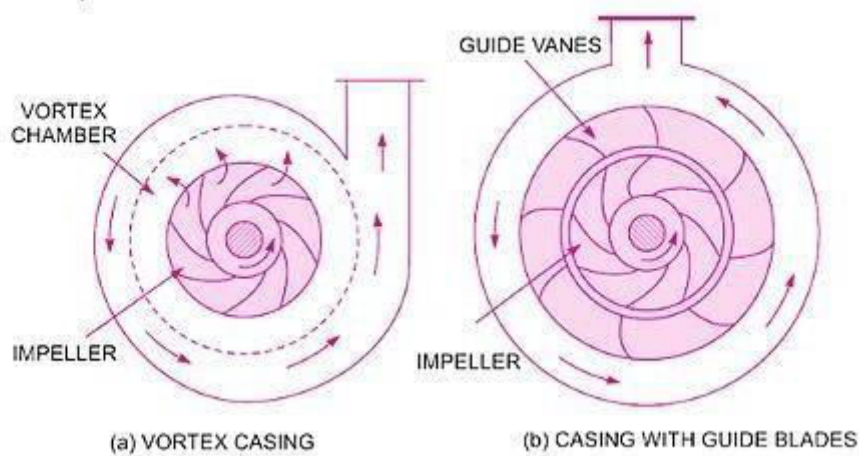


Fig. 24.1. Centrifugal pump with volute chamber.



(c) Casing with guide blades:

In this type of casing the impeller is surrounded by a series of guide blades mounted on a ring which is known as diffuser. The guide vanes are designed in such a way that the water from the impeller enters the guide vanes without shock.

3) Suction pipes with a foot valve and a strainer

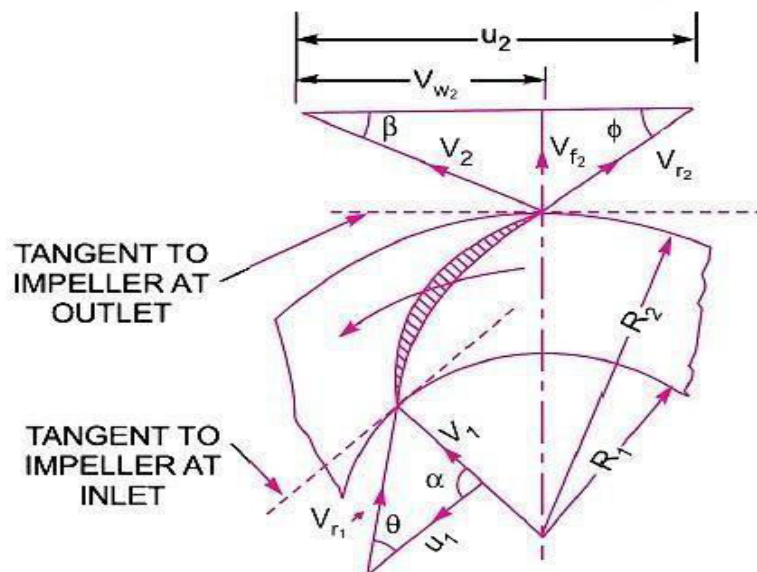
A pipe whose one end is connected to the inlet of the pump and other end dips into water in a sump is known as suction pipe. A foot valve which is a nonreturned valve is fitted at the lower end of the suction pipe. The foot valve opens only in upward direction. A strainer is also fitted at the lower end of the suction pipe.

4) Delivery pipe

A pipe whose one end is connected to the outlet of the pump and other end delivers the water at a required height is known as delivery pipe

VELOCITY TRIANGLES AND WORKDONE BY CENTRIFUGAL PUMP

In case of centrifugal pump the work is done by the impeller on the water the expression for the work done by the impeller on water is obtained by drawing the velocity triangles.



Let 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

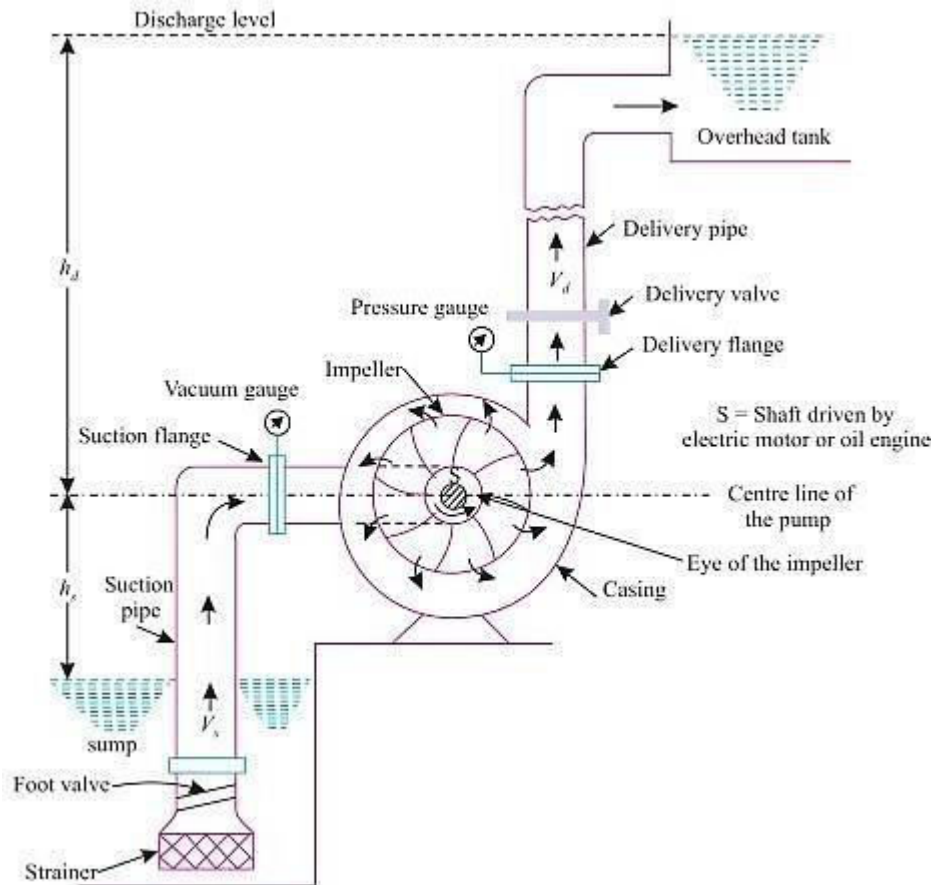
$Q = \pi \times D_1 \times B_1 \times V_{f1} = \pi \times D_2 \times B_2 \times V_{f2}$

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.

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

Different types of heads of a centrifugal pump



1) Suction head

It is the vertical height of the centre line of the centrifugal pump above the water surface in the tank or pump from which water is to be lifted. This height is also called suction lift and is denoted by h_s .

2) Delivery height

The vertical distance between the centre line of the pump and the water surface in the tank to which water is to be delivered is known as delivery head. It is denoted by h_d .

3) Static head

the sum of suction head and delivery head is known as static head. This is denoted by H_s and is written as

$$H_s = h_s + h_d$$

4) Manometric head

The manometric head is defined as the head against which a centrifugal has to work. It is denoted by H_m .

It is given by the following expressions-

$$(a) H_m = \text{head imparted by the impeller to the water} - \text{loss of head in the pump} \\ = \frac{V_w u_2^2}{g} - \text{loss of head in impeller}$$

$$= \frac{V_w u_2^2}{g} \text{ (if loss of pump is zero)}$$

$$(b) H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{V_d^2}{2g}$$

where,

h_s = suction head

h_d = delivery head

h_{fs} = head lost due to friction in
suction pipe

h_{fd} = head lost due to friction in delivery pipe

EFFICIENCIES OF CENTRIFUGAL PUMP

(a) MANOMETRIC EFFICIENCY:

The ratio of the manometric head to the head imparted by the impeller to the water is known as manometric efficiency.

$$\eta_{man} = \frac{\text{Manometric head}}{\text{head imparted by the impeller to water}} \\ = \frac{g \times H_m}{V_w u_2^2}$$

b) Mechanical efficiency

The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump is known as mechanical efficiency.

η_m = work done by the impeller per second / 1000

$$\eta_m = \frac{(W/g) \times V_w u_2^2 / 1000}{\text{shaft power}}$$

c) OVERALL EFFICIENCY

It is defined as the ratio of power output of the pump to the power input to the pump.

$$\eta_o = \frac{\text{weight of water lifted} \times H_m / 1000}{W} = \frac{W H_m}{1000 W}$$

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

Problem no- 01

The internal and external diameters of the impeller of a centrifugal pump are 200 mm and 400 mm respectively. The pump is running at 1200 rpm. The vane angles of the impeller at inlet and outlet are 20° and 30° respectively. The water enters the impeller radially and velocity of the flow is constant. Determine the work done by the impeller per unit weight of water?

Solution-data given

Internal diameter of impeller, $D_1 = 200 \text{ mm} = 0.20 \text{ m}$

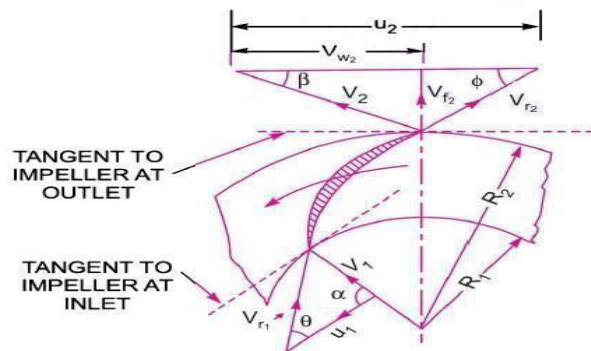
External diameter of impeller, $D_2 = 400 \text{ mm} = 0.40 \text{ m}$

Speed $N = 1200 \text{ rpm}$

Vane angle at inlet, $\theta = 20^\circ$

Vane angle at outlet, $\Phi = 30^\circ$

Water enters radially means, $\alpha=90^\circ$ and $V_{w1}=0$
 Velocity of flow $V_{f1}=V_{f2}$



Tangential velocity of impeller at inlet and outlet are

$$u_1 = \pi D_1 N/60 = \pi \times .20 \times 1200/60 = 12.56 \text{ m/s}$$

$$u_2 = \pi D_2 N/60 = \pi \times .40 \times 1200/60 = 25.13 \text{ m/s}$$

from the inlet velocity triangles,
 $\tan \theta = V_{f1}/u_1 = V_{f1}/12.56 \text{ m/s}$
 $V_{f1} = 12.56 \tan \theta = 12.56 \times \tan 20 = 4.57 \text{ m/s}$
 $V_{f2} = V_{f1} = 4.57 \text{ m/s}$
 from the inlet velocity triangles,
 $\tan \Phi = V_{f2}/(U_2 - V_{w2}) = 4.57/(25.13 - V_{w2})$

$$25.13 - V_{w2} = 4.57 / \tan \Phi = 7.915$$

$$V_{w2} = 25.13 - 7.915 = 17.215 \text{ m/s}$$

The work done by impeller per kg of water per second =

$$1/g (V_{w2} u_2) = 17.215 \times 25.13 / 9.81 = 44.1 \text{ Nm/N(Ans)}$$

2.3 Problem no-02

A centrifugal pump is to discharge $0.118 \text{ m}^3/\text{s}$ at a speed of 1450 rpm against a head of 25m. the impeller diameter is 250 mm its width at outlet is 50mm and manometric efficiency is 75 percent. Determine the vane angle at outer periphery of the impeller?

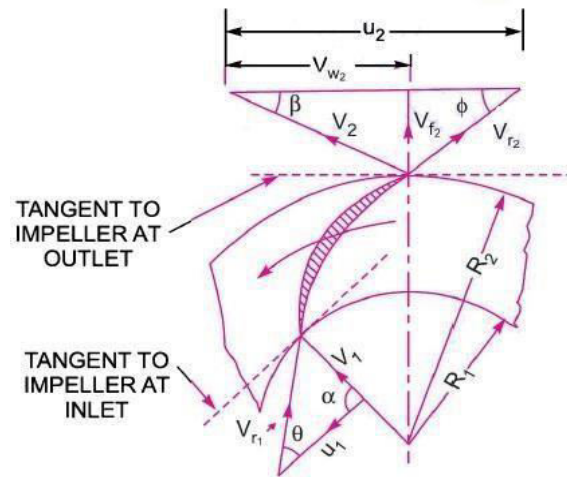
solution

discharge (Q) = $0.118 \text{ m}^3/\text{s}$

speed, N = 1450 rpm

Head $H_m = 25 \text{ m}$

Diameter at outlet $D_2 = 250 \text{ mm} = 0.250 \text{ m}$



Width at outlet , $B_2 = 50 \text{ mm} = 0.05 \text{ m}$

Manometric efficiency, $\eta_m = 75 \% = 0.75$

Tangential velocity of impeller at outlet, $u_1 = \pi D_1 N/60$
 $= \pi \times 0.25 \times 1450/60 = 18.98 \text{ m/s}$

Discharge $Q = \pi \times D_2 \times B_2 \times V_{f2}$

$V_{f2} = Q / \pi \times D_2 \times B_2 = 0.118 / \pi \times 0.25 \times 0.05$

Manometric efficiency $\eta_{man} = g \times H_m / V_{w2} \times u_2$

$V_{w2} = 9.81 \times 25 / \eta_{man} \times 18.98 = 17.23 \text{ m/s}$

From the outlet triangle, $\tan \Phi = V_{F2} / (U_2 - V_{w2})$

$$= 3 / (18.98 - 17.23) = 1.713$$

$$\Phi = 59.74^\circ \text{ (ans)}$$

SHORT QUESTIONS

01. What cavitation? 2019(S)

Ans- cavitation the phenomenon of formation of vapour bubbles and cavities around the impeller when the pressure around the impeller falls below the vapour pressure.

LONG QUESTIONS

1. Explain the construction and working principle of a centrifugal pump with neat sketch. 2019(S)

2. Find the maximum speed at which a centrifugal pump will start functioning against a head of 7.5 m if the diameters of impeller at outlet and inlet are respectively 100 cm and 50 cm. 2018(S)
3. The impeller of a centrifugal pump is 30 cm outside diameter. The impeller vane angles are 30 and 25 at the inner and outer periphery respectively and the speed is 1450 rpm. The velocity of flow through the impeller is constant. Find the work-done by the impeller per kg of water. 2018(S)
4. What is cavitation. What are the effect of Cavitation. How cavitation can be prevented. 2019(S)
5. The external and internal diameters of the impeller of a centrifugal pump are 100 cm and 500 cm respectively. The vane angles of inlet and outlet are 30° and 45° respectively and speed of the impeller is 1000rpm. Assuming constant velocity of flow, calculate work-done by the impeller per KN weight of work-done. 2019(S)

CHAPTER NO -03

RECIPROCATING PUMPS

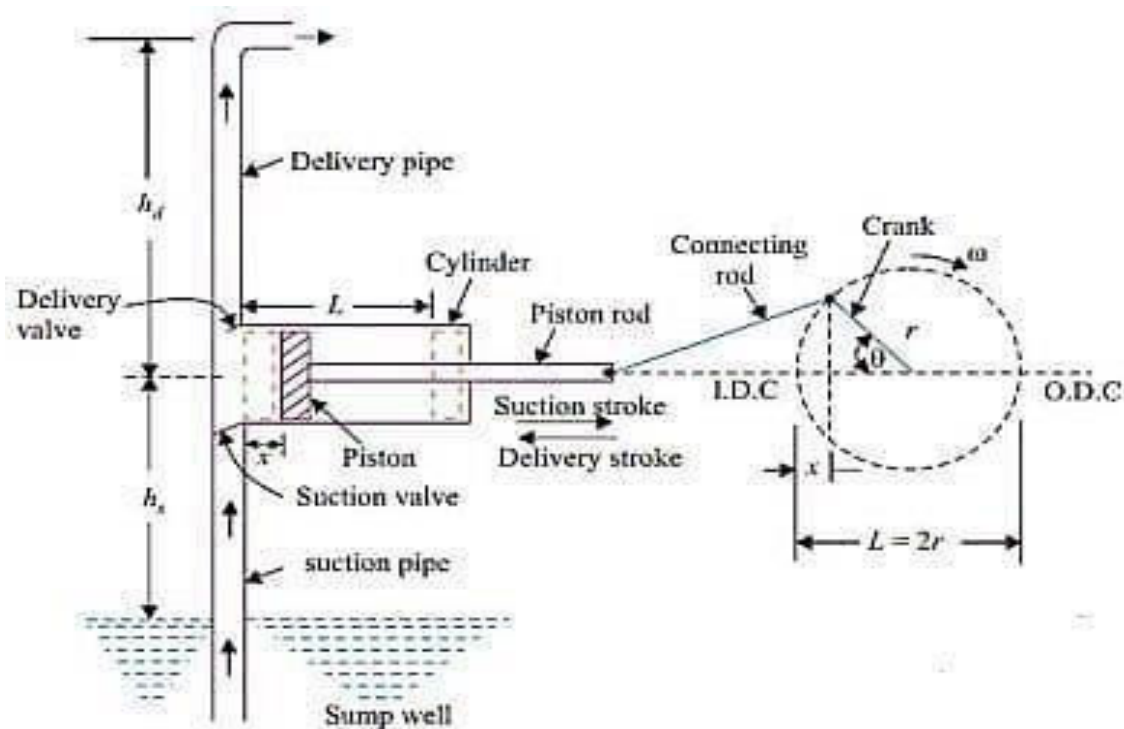
INTRODUCTION:

The hydraulic machine which convert mechanical energy into hydraulic energy is called pump. The hydraulic energy in the form of pressure energy. If the mechanical energy is converted into pressure energy by means of reciprocating motion of the piston cylinder arrangement then this type of pump is known as reciprocating pump.

CONSTRUCTION AND WORKING PRINCIPLE OF SINGLE ACTING RECIPROCATING PUMP

The main components of reciprocating pump are as follows:

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



1. Suction Pipe

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

2. Suction Valve

Suction valve is a 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 is also a 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 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 delivery 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

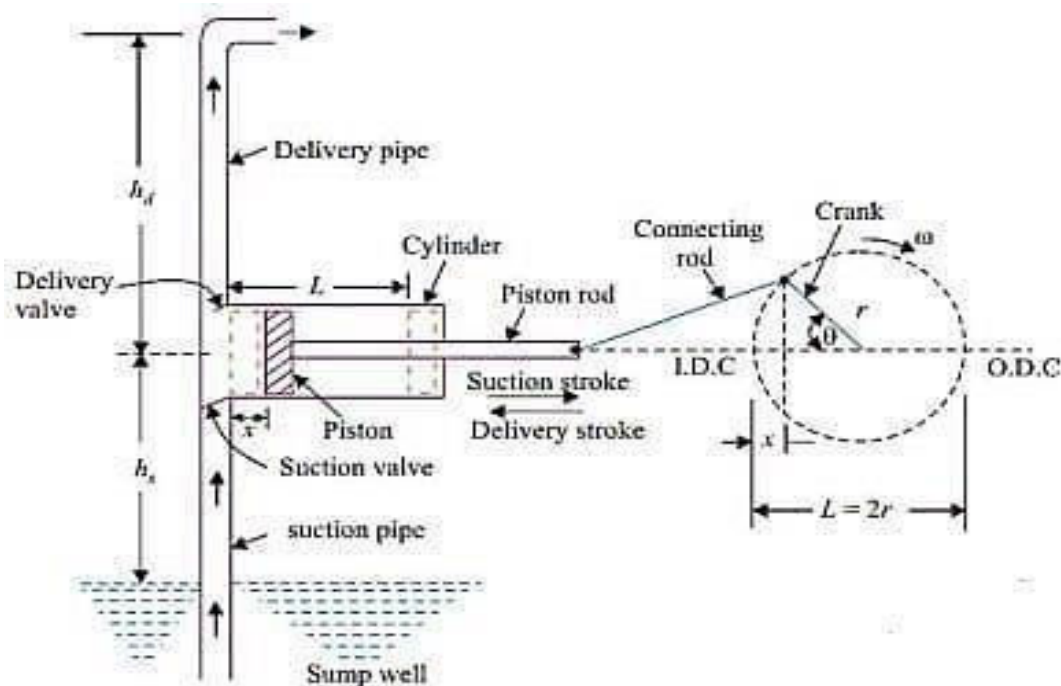
Strainer is provided at the end of suction pipe to prevent the entrance of solids from water source into the cylinder.

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.

N = revolutions of crank per minute

WORK DONE BY RECIPROCATING PUMP

Single acting pump:- In the single acting pump, as explained earlier, it has only one suction stroke and one delivery stroke for one revolution of the crank. It delivers the liquid only during the delivery stroke. Hence, the flow rate of the liquid delivered per second.

$$Q = ALN/60 \quad (1)$$

L = length of stroke

= 2r = radius of piston

A = Cross-section of cylinder.

The theoretical work done by the pump

$$W_{\text{net}} = \rho g Q(H_s + H_d) \quad (2)$$

H_s = suction head H_d

= delivery head

$$W_{\text{net}} = \rho g(ALN)(H_s + H_d) / 60$$

PROBLEM-01

A single acting reciprocating pump, running at 50 rpm, delivers 0.01 m³/s of water the diameter of the piston is 200 mm and stroke length 400 mm. Determine:

- The theoretical discharge of the pump
- Coefficient of discharge and
- Slip and the percentage of slip of the pump?

Data given N=50

rpm Q=0.01 m³/s

D=200 mm

L=400 mm

Area of the pump (A) = $(\pi/4) \times D^2 = (\pi/4) \times 0.2^2 = 0.0314 \text{ m}^2$ Theoretical

discharge of a single acting pump (Q_{th}) = ALN/60

$$= 0.0314 \times 0.4 \times 50 / 60 = 0.0104 \text{ m}^3/\text{s}$$

Coefficient of discharge (c_d) = Q_{act} / Q_{th} = 0.01 / 0.0104

$$= 0.955 \text{ (ans)}$$

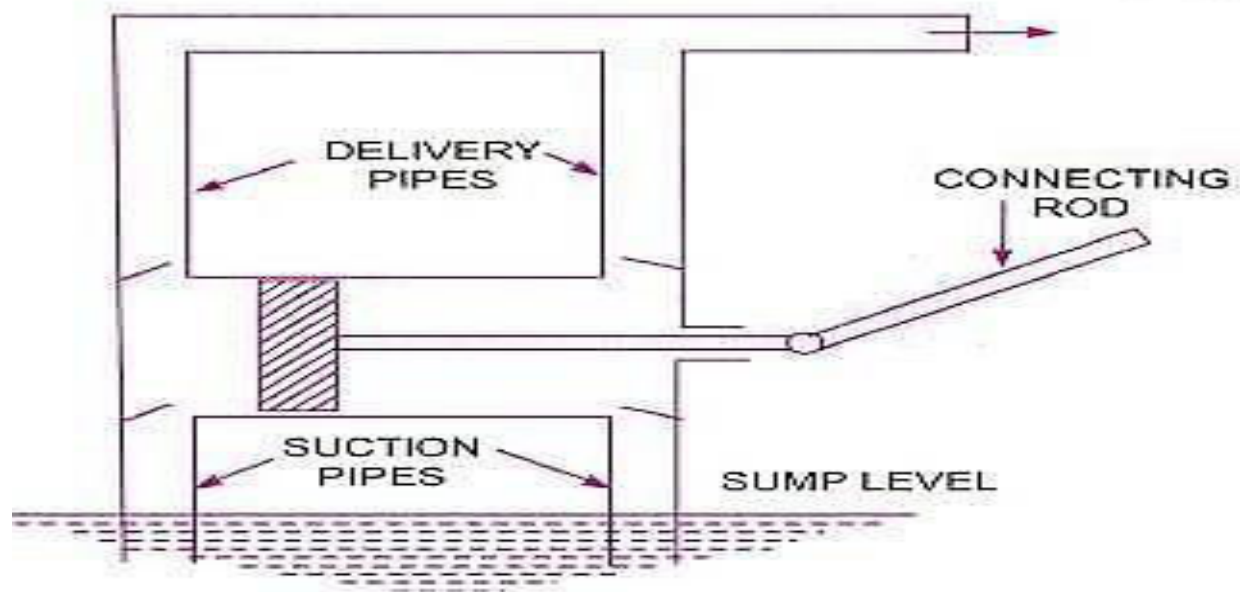
$$\text{Slip} = Q_{\text{th}} - Q_{\text{act}} = 0.0104 - 0.01 = 0.0004 \text{ m}^3/\text{s} \text{ (ans)}$$

$$\text{Percentage of slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$$

$$= \frac{0.0004}{0.01} \times 100 = 4.4 \text{ percent (ans)}$$

CONSTRUCTION AND WORKING PRINCIPLE DOUBLE ACTING RECIPROCATING PUMP

Water will be acting on both side of the piston in case of double acting reciprocating pump as displayed here in below figure. Therefore, there will be two suction and two delivery pipes for double acting reciprocating pump as shown in below.



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, $A = \frac{\pi}{4} \times D^2$

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

Discharge of the double acting reciprocating pump

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

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

$$V = AL + A_1L = (A + A_1)L = \left[\frac{\pi}{4} D^2 + \frac{\pi}{4} (D^2 - d^2) \right] \times L$$

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 \times No. of revolution in one

second

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

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 per second by the pump

$$w = (2\rho g ALN(h_s + h_d))/60$$

power developed

$$p = (2\rho g ALN(h_s + h_d))/60000$$

Problem -02

A double acting reciprocating pump running at 40 rpm, is discharging at 1.0 m³ of water per minute. The pump has a stroke of 400mm the diameter of the piston is 200mm, the delivery and suction head are 20 m & 5 m respectively find the slip of the pump and power required to drive the pump?

Solution data given

$$N = 40 \text{ rpm}$$

$$Q = 1 \text{ m}^3/\text{m} = 0.016 \text{ m}^3/\text{s}$$

$$400 \text{ mm} = 0.4 \text{ m} \quad D = 200 \text{ mm} =$$

$$0.2 \text{ m}$$

$$H_d = 20 \text{ m}$$

$$H_s = 5 \text{ m}$$

$$\text{Area of the pump} = (\pi/4) \times D^2 = (\pi/4) \times 0.2^2 = 0.0166 \text{ m}^2 \text{ Theoretical}$$

$$\text{discharge of the pump } (Q_{th}) = 2ALN/60$$

$$= 2 \times 0.0166 \times 0.4 \times 40 / 60 = 0.01675 \text{ m}^3/\text{s} \text{ Slip} = Q_{th} -$$

$$Q_{act} = 0.01675 - 0.016 = 0.00075 \text{ m}^3/\text{s}$$

Power required to drive the double acting pump

$$p = (2\rho g A(hs + hd))/60000$$

$$= 2 \times 1000 \times 9.81 \times 0.0166 \times 0.4 \times 40 \times 25 / 60000$$

$$= 4.109 \text{ kw(Ans)}$$

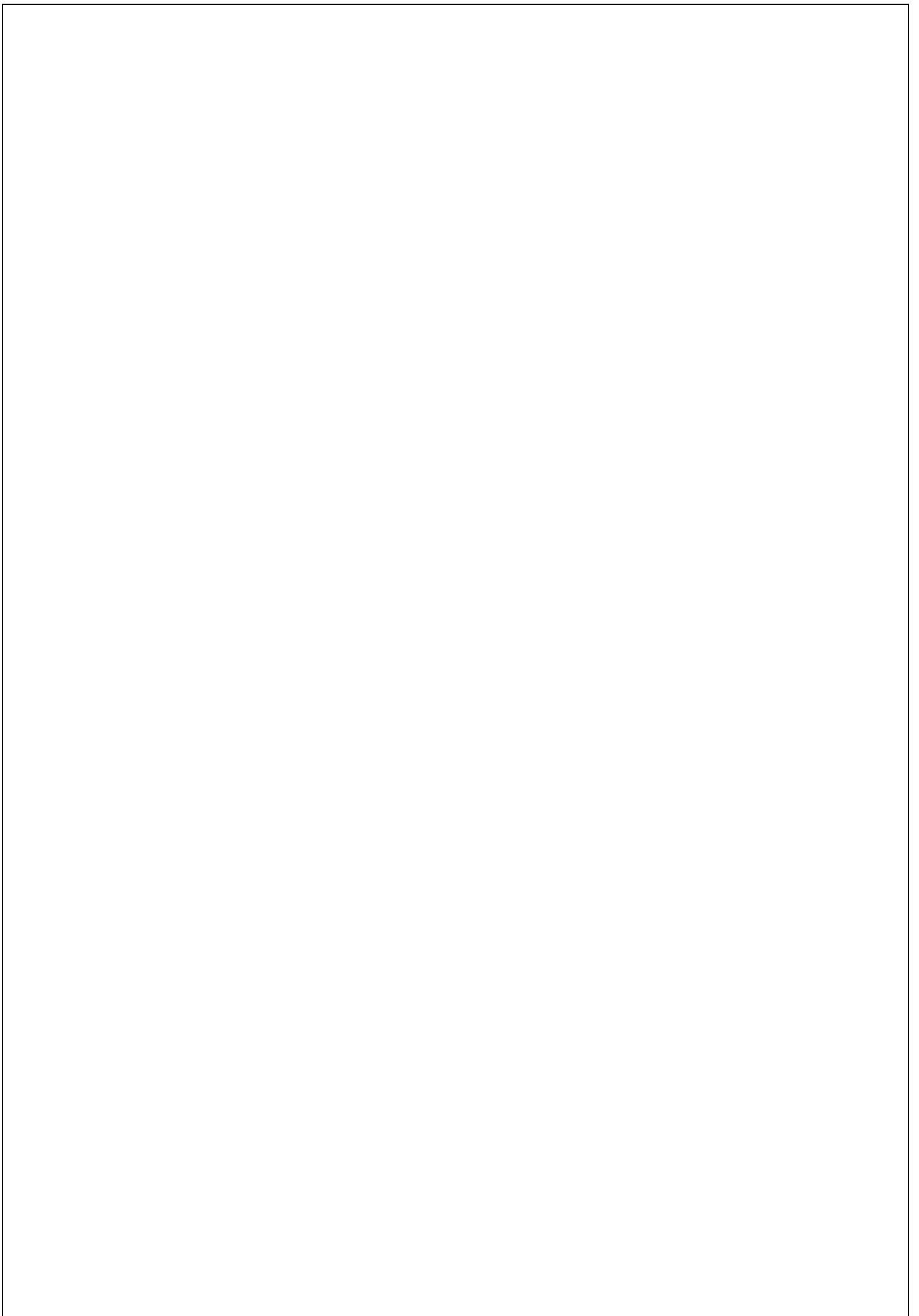
POWER REQUIRED TO DRIVE THE PUMP

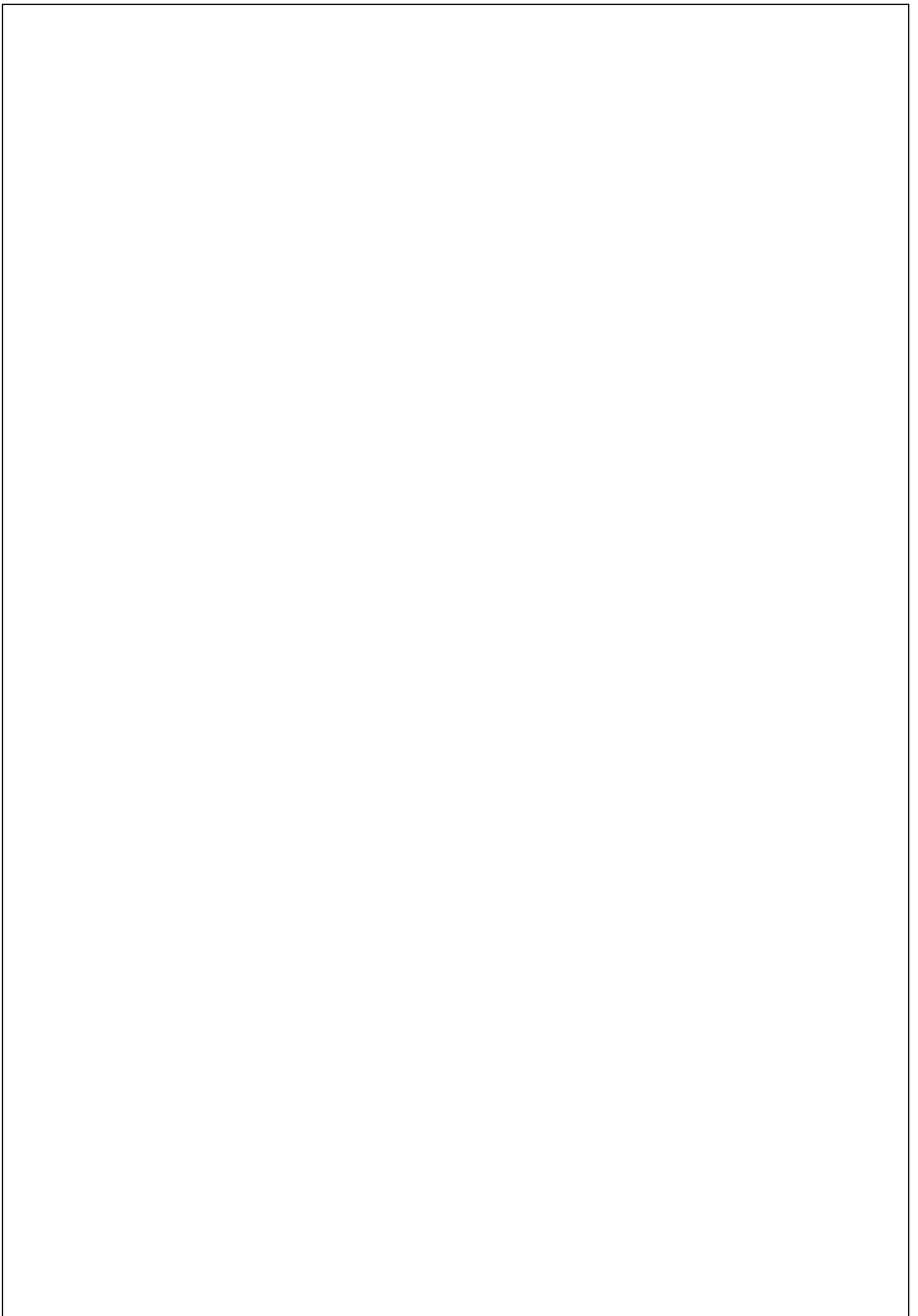
Power required to drive the single acting pump

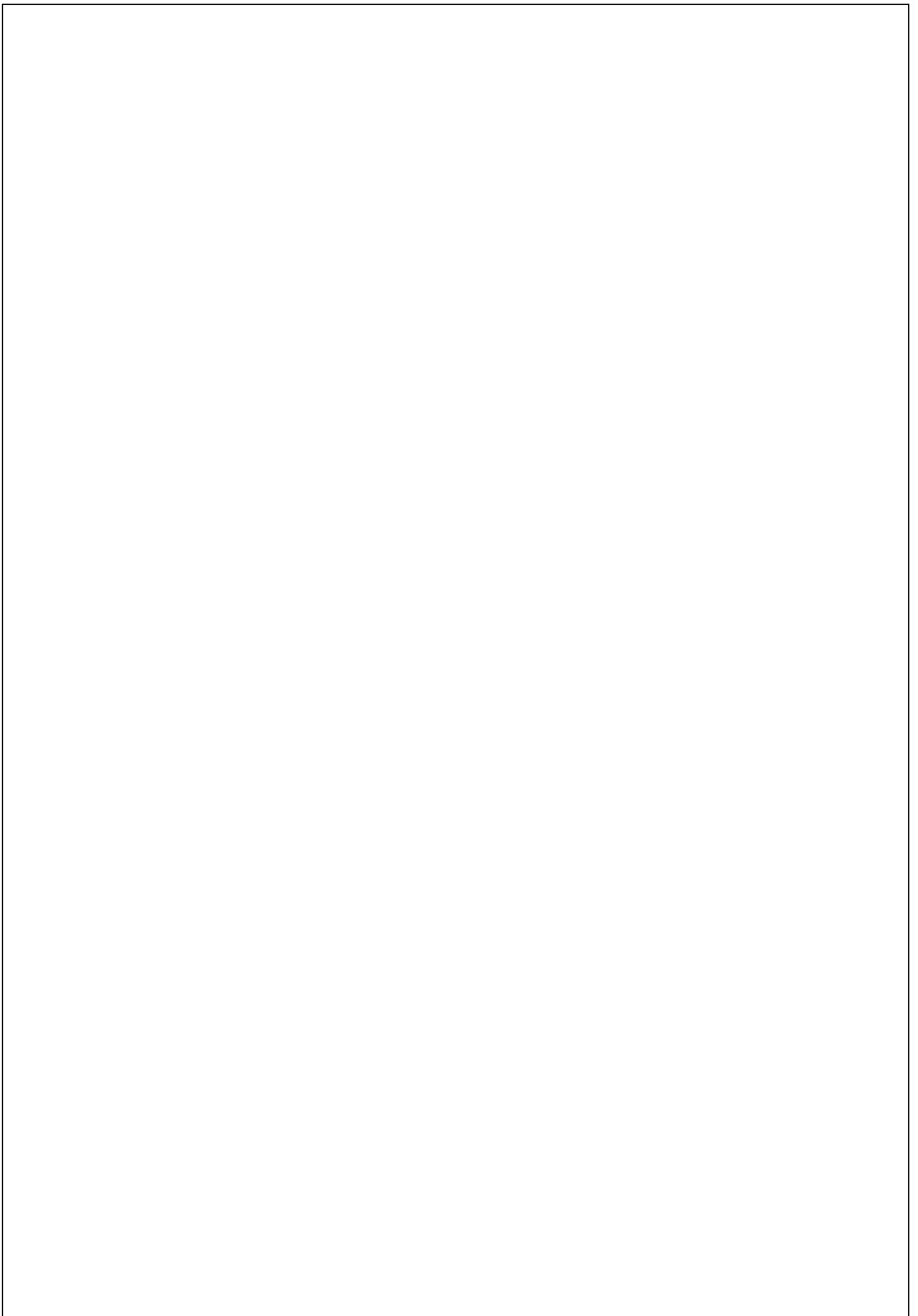
$$p = (\rho g A(hs + hd))/60000$$

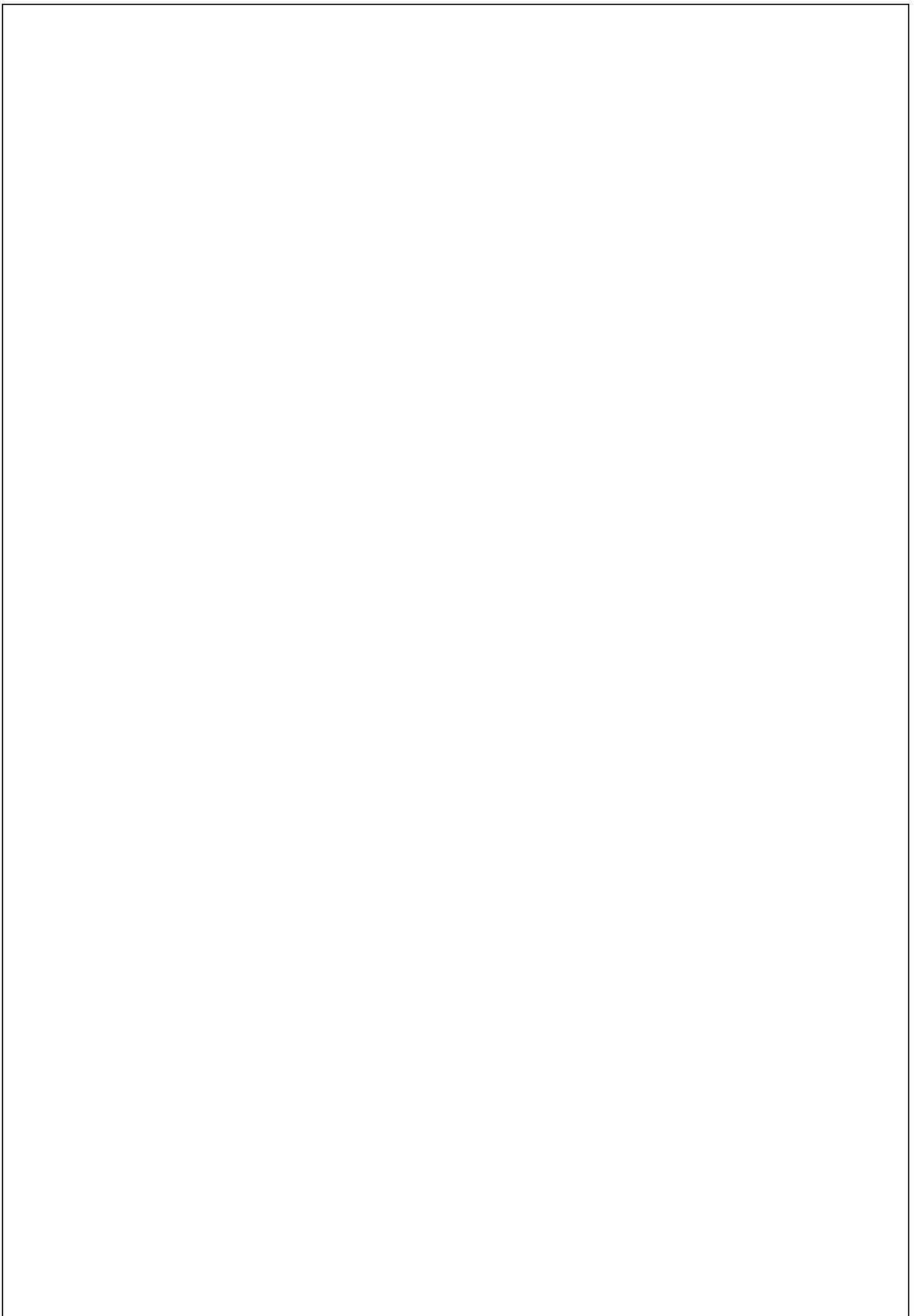
Power required to drive the double acting pump

$$p = (2\rho g A(hs + hd))/60000$$









& 3.5 SLIP OF RECIPROCATING PUMP AND PERCENTAGE OF SLIP

- Slip of pump is defined as the difference between the theoretical discharge(Q_{th}) and actual discharge(Q_{act}).

$$\text{Slip} = (Q_{th} - Q_{act})$$

$$\text{Percentage Slip} = (Q_{th} - Q_{act})/Q_{th} \times 100 \text{ where}$$

C_d = Co-efficient of discharge

$$\text{Percentage slip} = (1 - C_d) \times 100$$

Negative Slip: In most of the cases, the slip is positive. But in some cases, the actual discharge of the pump may be more than the theoretical discharge in which case C_d will be more than one and the slip will be negative, which is known as negative slip. This occurs in pumps having long suction pipe and low delivery head, especially when these are running at high speed. This is due to the reason that the inertia pressure in the suction pipe becomes so large that it causes the delivery valve to open before the suction stroke is completed. Thus, some liquid is pushed directly into the delivery pipe even before the delivery stroke is commenced. This results in making the actual discharge more than the theoretical discharge.

Relation between percentage slip and coefficient of discharge

$$\text{Percentage slip} = (1 - C_d) \times 100$$

3.6 PROBLEM – 03

The cylinder bore diameter of a single acting reciprocating pump is 150 mm and its stroke is 300 mm. The pump runs at 50 r.p.m. and lifts water through a height of 25 m. The delivery pipe is 22m long and 100mm in diameter. Find The cylinder bore diameter of a single acting reciprocating pump is 150 mm and its stroke is 300 mm. The pump runs at 50 r.p.m. and lifts water through a height of 25 m. The delivery pipe is 22m long and 100mm in diameter. Find the theoretical discharge and theoretical power required to run the pump. If the actual discharge is 4.2 liters/s, find the percentage of slip.

v the theoretical discharge and theoretical power required to run the pump. If the actual discharge is 4.2 liters/s, find the percentage of slip.

DATA GIVEN

Diameter of cylinder, $D=150\text{mm}=0.15\text{m}$ Area, $A=$

$$\pi/4 \times D^2 = \pi/4 \times 0.15^2 = 0.01767\text{m}^2$$

Stroke, $L=300\text{mm}=0.3\text{m}$

Speed of the pump, $N=50$ r. p. m Total

height lifted, $H= 25\text{m}$ Length of

delivery pipe, $L_d = 22\text{m}$

Diameter of delivery pipe, $D_d = 100\text{mm} = 0.1\text{m}$ Actual

discharge, $Q_{act} = 4.2\text{liters/s} = 0.0042\text{m}^3/\text{s}$ Theoretical

discharge of the pump

$$Q_{th} = \frac{ALN}{60} = \frac{0.01767 \times 0.3 \times 50}{60} = 0.0044175 \text{ m}^3/\text{s} = 4.4175 \text{ litres/sec}$$

Theoretical power

Theoretical power = Theoretical weight of water lifted/s \times Total height/1000

$$= \rho \times g \times Q_{th} \times H / 1000$$

$$= 1000 \times 9.81 \times 0.0042 \times 25 / 1000 = 1.0833 \text{ kw}$$

The Percentage of Slip

$$\% \text{ slip} = \left(\frac{Q_{th} - Q_{act}}{Q_{th}} \right) / 100 = \left(\frac{4.4175 - 4.2}{4.4175} \right) \times 100 = 4.92 \% \text{ (ans).}$$

SHORT QUESTIONS WITH ANSWER

1. What is slip in pump? 2018(s), 2019(s)

- slip may be defined as the difference between theoretical discharge to the actual discharge.
- Generally it is expressed as percentage of slip.
- Mathematically

$$\% \text{ slip} = \frac{\text{theoretical discharge} - \text{actual discharge}}{\text{theoretical discharge}}$$

2. Define about negative slip? 2019(s)

Ans- When the actual discharge is more than the theoretical discharge then negative discharge occurs. It is possible when the suction pipe is short and delivery pipe is long and the pump is running at high speed.

3. what is cavitation? 2019(s)

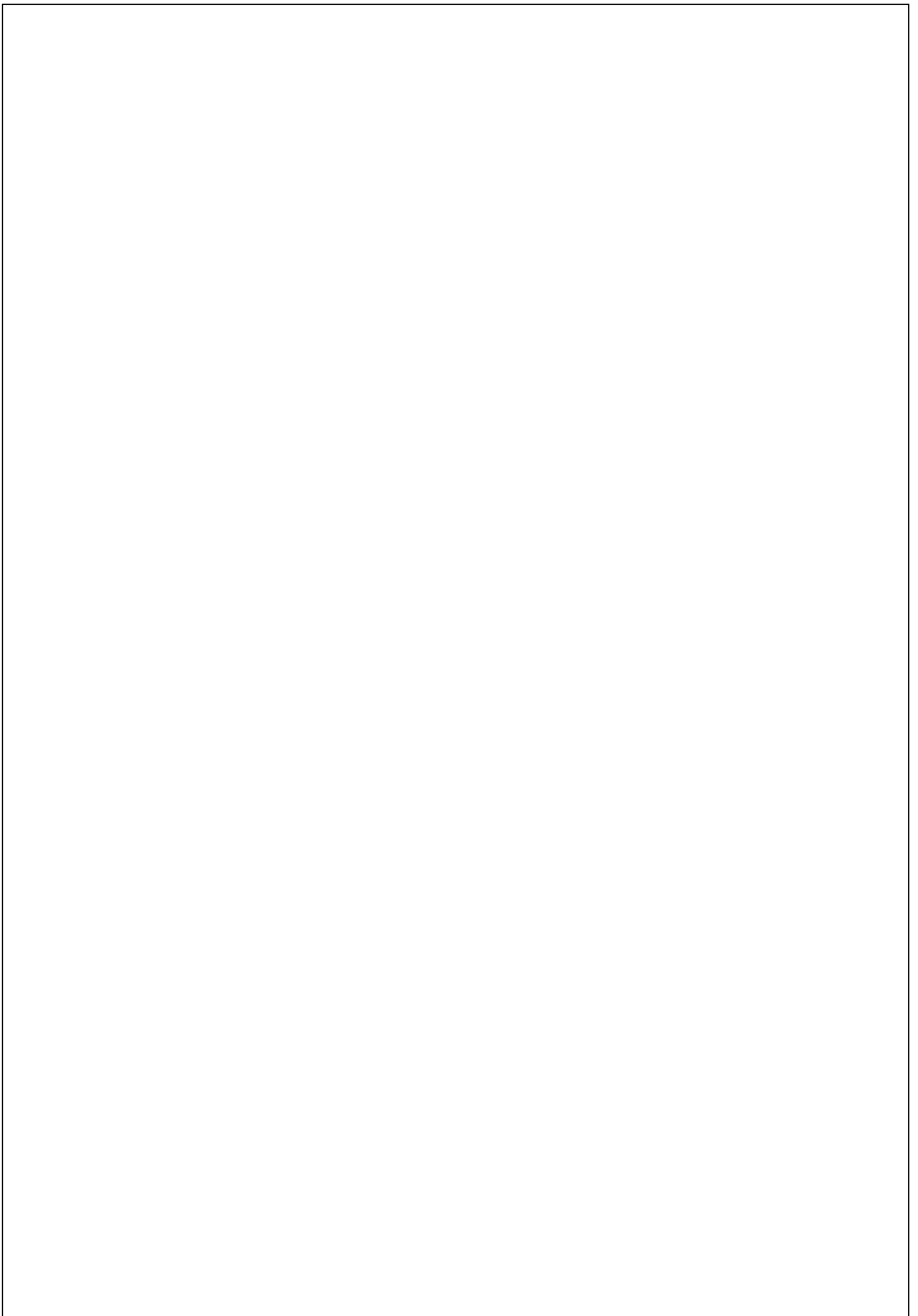
Ans- cavitation is the phenomenon of formation of vapor bubbles and cavities around the impeller when the pressure around the impeller falls below the vapor pressure.

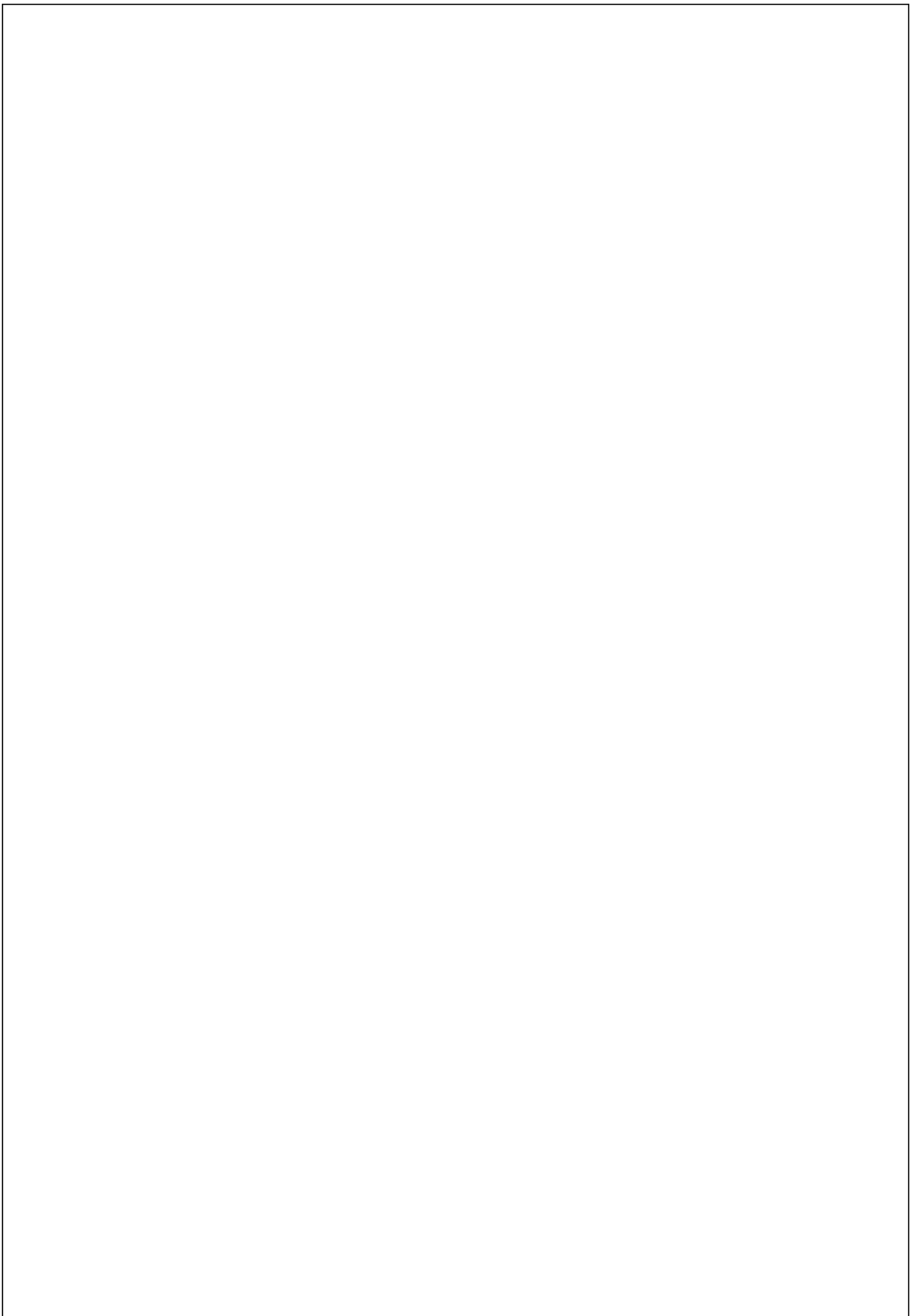
LONG QUESTIONS

1. Differentiate between reciprocating pump and centrifugal pump? 2018(s)

2. A single acting reciprocating pump running at 60 R.P.M. delivers $0.015 \text{ m}^3/\text{s}$ of water. The

diameter of the piston is 200 mm and stroke length 400 mm. determine theoretical discharge of the pump, Coefficient of discharge and slip of the pump. 2018(s)



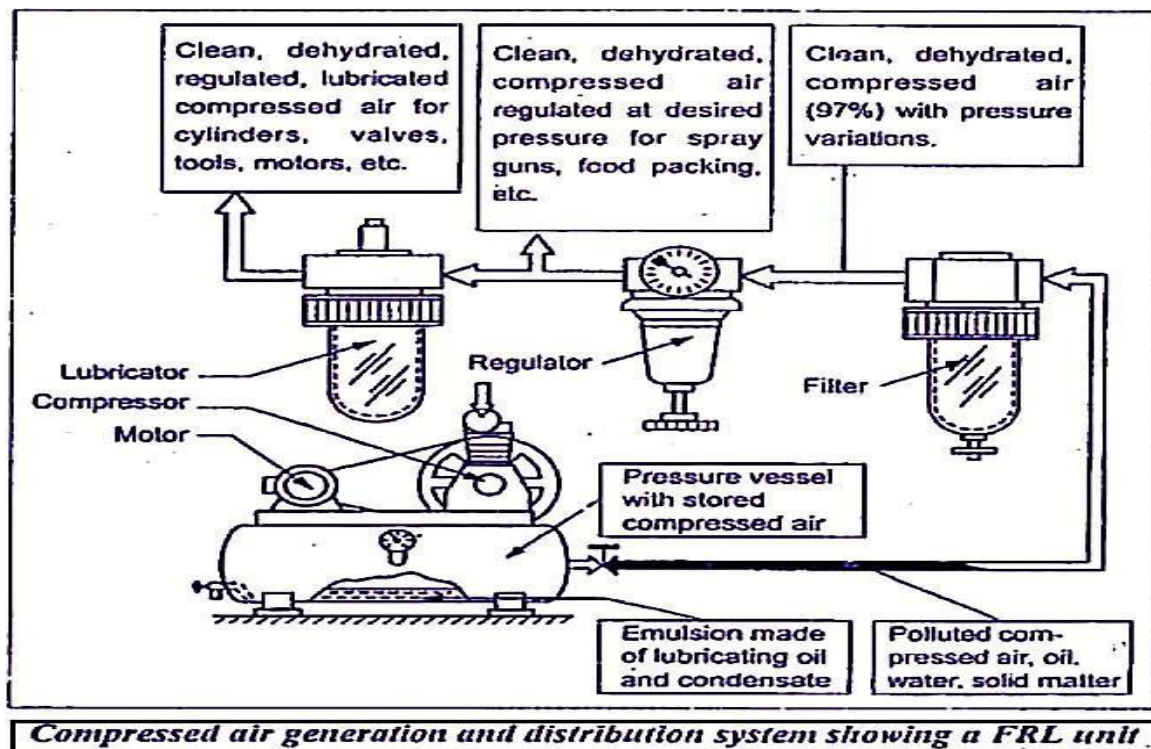


CHAPTER NO -04 PNEUMATIC CONTROL SYSTEM

ELEMENTS –FILTER-REGULATOR-LUBRICATION UNIT:

Filter, Pressure Regulator, and Lubricator are combined in a unit. These three units together are called FRL units or Service units.

Compressed air from compressor comes in FRL unit wherein, the air is filtered, controlled, and lubricated. Such prepared and controlled air is delivered to the pneumatic system.



Construction And Working of the FRL unit:

FRC unit means Filter Regulator Combine unit. Most of the pneumatic system uses FRL unit. The main elements of the FRL unit are Filter, Regulator, and Lubricator.

1. Filter:

Air enters the inlet port of the air filter through angled louvers. The centrifugal action of the rotating air causes the larger pieces of dirt and water particles to be thrown against the inner wall of the filter bowl. These contaminants then flow down into the bottom of the filter bowl.

A baffle prevents turbulent air from splashing water on to the filter element. The air then passes through the filter element, where the fine dirt particles are filtered out. The compressed air then exits through the outer port to the regulator.

2. Relieving or Venting Type Pressure regulator:

Outlet pressure is sensed by a diaphragm preloaded with an adjustable pressure setting spring. The compressed air, which flows through a controlled cross-section at the valve seat, acts on the other side of the diaphragm. The diaphragm has a large surface area exposed to secondary (outlet) pressure and is quite sensitive to its fluctuations. The movement of the diaphragm regulates the pressure.

3. Lubricator:

As air enters the lubricator, its velocity is increased by a venture ring. The pressure at the venture ring will be lower than the atmospheric pressure and the pressure on the oil is atmospheric. Due to this pressure difference between the upper chamber and lower chamber, oil will be drawn up in a riser tube. Oil droplets mix with the incoming air and form a fine mist. The needle valve is used to adjust the pressure difference across the oil jet and hence the oil flowrate. The air the oil mixture is forced to rotate as it leaves the central cylinder so that large particles of oil goes back to bowl and only the mist goes to outlet.

PRESSURE CONTROL VALVES:

- A pneumatic flow control valve circulates air throughout a larger pneumatic system by either allowing or inhibiting the flow of pressurized air, whose force is then used to power a device. Because valves can have varying numbers of entryways for air, creating different flow patterns, valves are classified according to the number of ports they possess and the flow-paths they create. Additionally, because they can move air in a variety of ways, they can suit a variety of applications.
- Aside from the commonly used directional control valves, there are valves that are designed to serve more specific purposes, such as pressure regulator, venting-type regulator valves, and needle valves. Pressure and venting-type valves both help control pressure, whereas needle valves help control the flow within a pneumatic pressure system.
- There are various type of pressure control valves

1-Pressure regulator

2-venting regulator

3-Needle valves

4-Two valves

PRESSURE RELIEF VALVES:

- Pressure relief valves are the quite common valves used in pneumatic industries for performing two important functions as mentioned here-
 1. Protection against overload for various circuit components.
 2. Limiting the force or torque applied by actuators

- Pressure relief valve will have two sections i.e. body section and pilot valve section. Body section of relief valve will have a piston or seat due to the action of spring force. Pilot valve section will control the piston movement with the help hydraulic force.
- We can see one simple type of pressure relief valve in following fig. one of the pressure relief valve will be connected with pump delivery line or pressure line and other port will be connected with pneumatic reservoir. Poppet will be positioned to its seat due to the spring force, one adjusting pressure of relief valve.
- If pressure at the inlet of relief valve is not enough to overcome the spring force in that situation poppet will be remain seated over its seat and will not allow the flow of fluid through it and therefore relief valve will be closed and will not allow flow through it.
- When pressure at the inlet of relief valve increases and overcomes the spring force which was adjusted with the help of pressure adjusting screw displaced at the top of relief valve in that situation poppet will leave the seat and will permit the flow of fluid through relief valve.
- Hence, if pressure at inlet of relief valve overcomes the setting pressure, poppet will again positioned to its seat due to the action of spring force and relief valve will be closed and will not allow the flow through it.
- Cracking pressure in relief valve operation is defined as the pressure at which relief valve operation is defined as the pressure at which relief valve first permit the flow through it. Pressure at which relief valve allows to flow the full rated capacity will be termed as valve full flow pressure.

PRESSURE REGULATION VALVES:

- The principal parts of the pressure regulation valve are the main valve, an upward-seating valve that has a piston on top of its valve stem an upward seating auxiliary valve, a controlling diaphragm and an adjusting spring and screw.
- A pressure regulation valve uses a spring loaded spool to control the down stream pressure. If the down stream pressure is below the valve setting, the fluid flows freely from the inlet to the outlet.
- Regulation valve operation is controlled by high pressure at the valve inlet and the adjusting screw on the top of the valve assembly. The pressure entering the main valve assists the main valve spring in keeping the reducing valve closed by pushing upward on the main valve disk.
- However, some of the high pressure is bled to an auxiliary valve on top of the main valve. The auxiliary valve controls the admission of the high pressure to the piston on top of the main valve. The piston has a large surface area than the main valve disk, resulting in a net downward force to open the main valve. The auxiliary valve is controlled by a controlling diaphragm located direction over the auxiliary valve.
- The controlling diaphragm transmits a downward force that tends to open the auxiliary valve. The downward force is exerted by the adjusting spring, which is controlled by the adjusting screw. Reduced pressure from the main valve outlet is bled back to a chamber beneath the diaphragm to counteract the downward force of the adjusting spring.

DIRECTION CONTROL VALVES

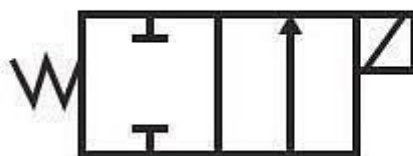
- In the pneumatic world, valves are the equivalent of relays controlling the flow of electricity in automation systems. Instead of distributing electric power to motors, drives and other devices, pneumatic valves distribute air to cylinders, actuators and nozzles.
- Pneumatic valves, also called directional control valves, are activated in a variety of ways including manually, solenoid operated and air piloted. In their simplest form, 2-way and 3-way valves can be normally open (NO) or normally closed (NC), terms that refer to their normal states without power applied. Another very common valve is a 4-way valve which switches supply and exhaust between two outlet ports.
- Manually activated valves are typically switched open and closed by a foot pedal, toggle actuator, handle, knob or push button. An operator controls the activated position of the valve, and a spring or the operator returns the valve to its home position.
- Solenoid operated valves use an electrical coil to control the position of a poppet, plunger or spool to open or close a valve. Typical solenoid control voltages are 12VDC, 24 VAC/DC, 120VAC or 240VAC.
- Air piloted valves are operated by an external air source such as a solenoid operated valve in a remote location. The valve can also be internally air piloted, enabling use of a smaller integrated electric solenoid to provide an air pilot signal to control the larger valve spool.

3/2DCV,5/2 DCV,5/3DCV VALVE TYPES:

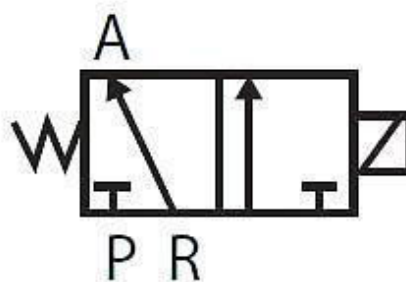
- With pneumatic valves, the configuration or valve type indicates how air is connected to the device and switched through the valve. This configuration has a strong influence on the device the valve is controlling, and understanding this is critical for specifying the proper valve for the application.
- The pneumatic symbol for a valve has three parts: actuation (how the valve is actuated), position (the number of positions and ports) and flow (how the air flows through the device). The actuation methods are on the left and right of the symbol, and can be thought of as pushing the boxes left or right.
- The number of boxes indicates the number of positions, typically two or three. Flow of supply air or exhaust, for each position, is defined by the information in each box.
- Each valve position has one or more flow paths, and the arrows in each box represent flow of air and exhaust. The point where each path touches a box is called a port, and to determine the number of ports, one must count a single box of the symbol. The flow path can also be blocked, indicated by a “T” symbol.
- The number of ports and positions define the type of work a valve is designed for, so selecting these options is a critical design decision. A 2-port or 2-way, 2-position valve has one inlet port and one outlet port. that is its only function.
- The number of different pathways for air to travel in or out of the valve are referred to as “ways” while the different available states are called “positions”. Valves commonly used in industrial applications are either a 2-, 3- or 4-way configuration, 2- and 3-way valves have 2 positions while 4-way valves can be either 2- or 3-position.

Common pneumatic valve types:

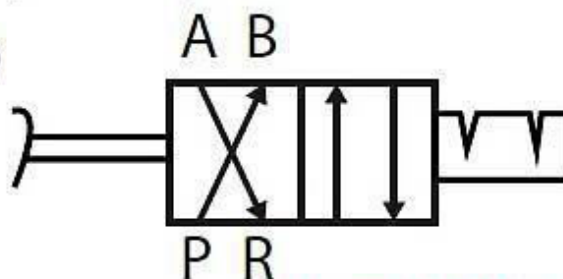
- 2-port (2-way), 2-position
- 3-port (3-way), 2-position
- 5-port (4-way), 2-position
- 5-port (4-way), 3-position

2-way, 2-position, normally closed direct-acting solenoid valve, spring return

InstrumentationTools.com

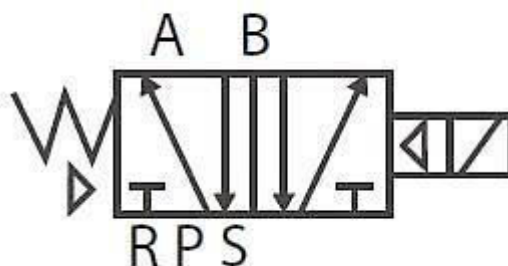
3-way, 2-position, normally closed direct-acting solenoid valve, spring return

InstrumentationTools.com

4-way, 2-position, detented rotary manual valve

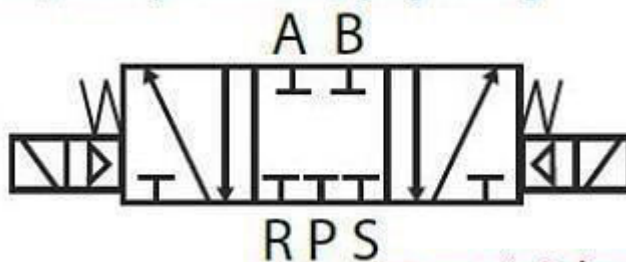
InstrumentationTools.com

4-way (5-port), 2-position, piloted solenoid valve, spring return



InstrumentationTools.com

4-way (5-port), 3-position closed center, double-piloted solenoid, spring centering



InstrumentationTools.com

- By adding a third port, the 3-port or 3-way, 2-position valve can both supply and exhaust pressure. The three ports are air in, air out and exhaust. While exhausting pressure is important for cylinder movement, this type of valve only works well in applications such as single-acting cylinders with a spring return, or in air blow off applications such as blowing chips in a machining process.
- Adding two more ports turns the valve into a 5-port (4-way), 2-position valve. A 5-port valve is technically a 4-way valve since there are two ports open to 'Exhaust'. This is mainly done to simplify valve construction.
- This is the most popular directional control valve because it can extend and retract double-acting cylinders, providing a wide range of control capabilities. This type of valve includes an inlet port, two outlet ports and two exhaust ports.
- In a 2-position configuration, one output is flowing air from the inlet and the other is flowing air to an exhaust port. When the valve is switched, the two outputs are in opposite modes. This is the most common way to extend and retract a double-acting pneumatic actuator, pressurizing one side of the cylinder while exhausting the other.
- Keep in mind that 2-position, single solenoid valves have a spring return. So with an energized valve, if the double-acting cylinder it's connected to is extending, that cylinder will retract if electrical power is lost (such as when an emergency stop is pressed) but air remains on. If the emergency stop also dumps air pressure in the system, as recommended, the cylinder will retract once pressure is restored unless the valve is re-energized.
- If a 2-position, double solenoid valve has a detent feature, the valve spool is held at whichever position it was at the moment the emergency stop was pressed.
- If the cylinder was at mid-stroke when the emergency stop was pressed, when air is reapplied, the valve will command the cylinder to continue motion to the original energized position, even with both solenoids on the valve de-energized. This motion, due to the maintained valve position, can cause issues.
- For example, unintended cylinder motion after an emergency stop can damage tooling and should be examined during design.

Flow control valves:

Flow Control Valves are used to reduce the rate of flow in a section of a pneumatic circuit, resulting in a slower actuator speed. Unlike a Needle Valve, a Flow Control Valve regulates air flow in only one direction, allowing free flow in the opposite direction.

Pneumadyne Air Flow Control Valves

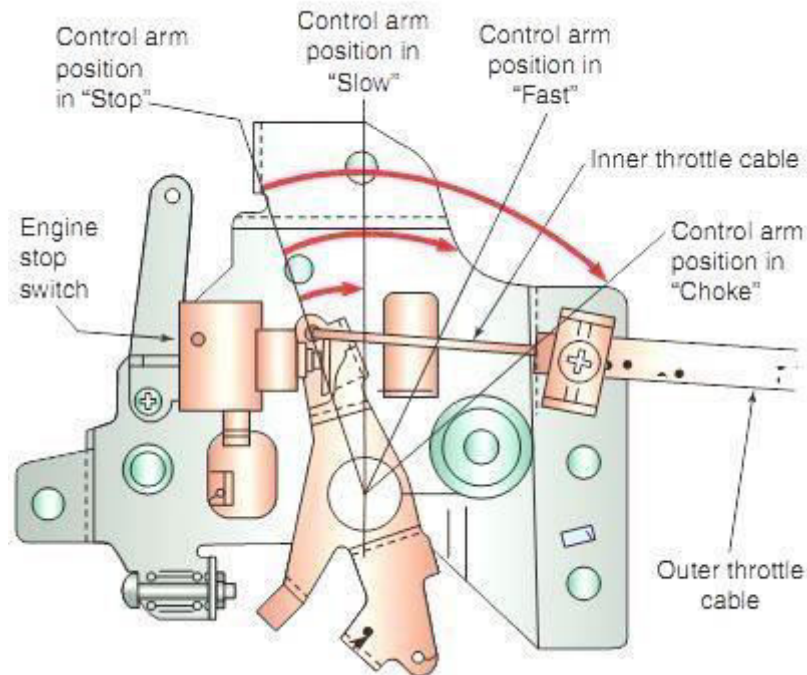
Pneumadyne's inline Flow Control Valves feature finely threaded stems that allow for gradual adjustment of the controlled flow passing through the valve. The pneumatic system's air flow enters via the input port, travels through an orifice sized by the tapered stem, and out via the output port. Our pneumatic flow control valves include a bypass check which allows rapid free flow from the output through the input port.

We offer two types of air flow control valves. Their selection and placement within a pneumatic circuit will greatly affect the function of an actuator.

- A meter-in flow control valve (also known as a reverse flow control valve) restricts the flow *to* an actuator.
- A meter-out flow control valve regulates the exhaust flow *from* an actuator. These are the most commonly used air flow control valve

THROTTLE VALVE

Throttle valve is one of the most simple and widely used as flow control valve and often equipped with a pressure relief valve to compose a variety of throttle speed in pneumatic circuit or system. Throttle Valves The flow of throttle valves is related to the pressure drop at the throttle position, i.e. a larger p results in a larger flow. The equation for the resistance coefficient shows the relationship to the viscosity. The shorter the throttle length l , the less noticeable is a change in viscosity. It should also be noted that the flow increases as the fluid becomes thinner. Whether a valve is dependent on the viscosity or is practically independent, depends on the construction of the throttle position. Throttle valves are used, when: - there is constant working resistance - change in speed is irrelevant or desired with changing load.

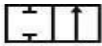
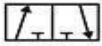


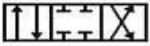
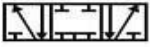

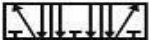


These throttle valves are related to pressure and viscosity. Oil reaches the throttle position 3 by means of side bores 1 in the housing 2. These are formed between the housing and the adjustable sleeve 4. By turning the sleeve, the ring-shaped section at the throttle position can be altered steplessly. There is throttling in both directions (fig.1). If throttling is required in one direction only, an additional check valve is necessary. In throttle direction, fluid reaches the rear side 1 of the valve poppet 2. The poppet of the check valve is pushed on its seat. Throttling procedure is as per type MG (fig 2). In the opposite direction, (right to left) the flow acts on the face surface of the check valve. The poppet is lifted from its seat. Oil flows unthrottled through the valve. At the same time, part of the fluid passes over the ring slot and thus the desired self-cleaning process is achieved.













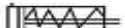






ISO SYMBOLS OF PNEUMATIC COMPONENTS

Pneumatic systems are still popular in old as well as modern plant. Pneumatic diagram represents the pneumatic system in defined ways they are represented. Following are the different symbols for different pneumatic components.

Pneumatic directional control valve

	2-position, 2-way, 2 ported
	2-position, 3-way, 3 ported
	2-position, 4-way, 4 ported
	2-position, 4-way, 5 ported
	3-position, 4-way, 4 ported Closed Center
	3-position, 4-way, 5 ported Closed Center
	3-position, 4-way, 5 ported Pressure Center
	3-position, 4-way, 5 ported Open Center

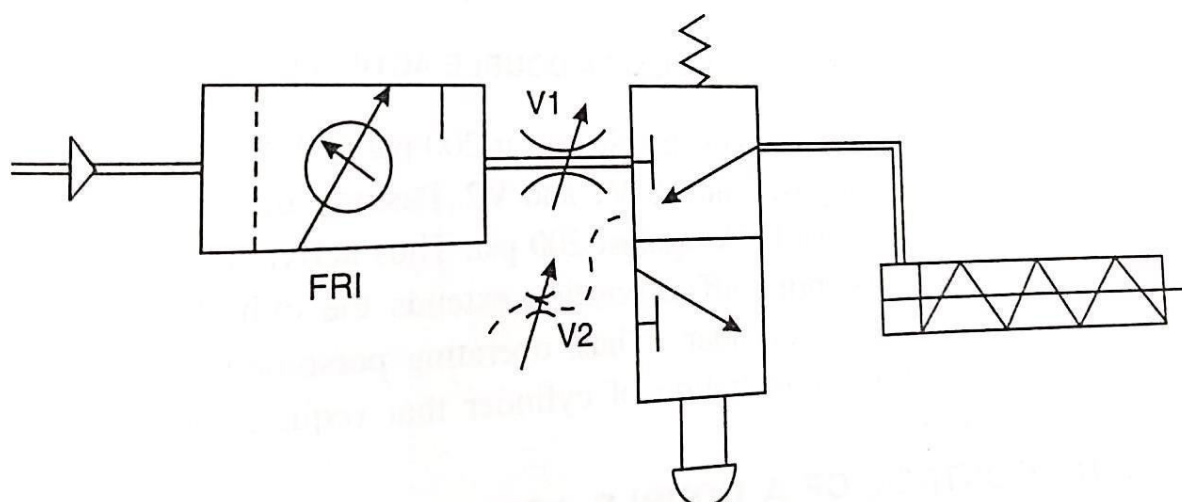
Symbols of common equipment used in pneumatic circuits

	Accumulator		Direction of Flow
	Air Dryer		Exhaust Line or Control Line
	Air Motor (One Direction Flow)		Filter
	Air Motor (Two Direction Flow)		Filter (Automatic Drain)
	Check Valve (Spring Loaded)		Filter (Manual Drain)
	Compressor		Fixed Restriction
	Cylinder (Spring Return)		Air Motor (Two Direction Flow)
	Cylinder Double Acting (Double Rod)		Lubricator
	Cylinder Double Acting (Single fixed cushion)		
	Cylinder Double Acting (Two adjustable cushions)		
	Differential Pressure		

PNEUMATIC CIRCUIT

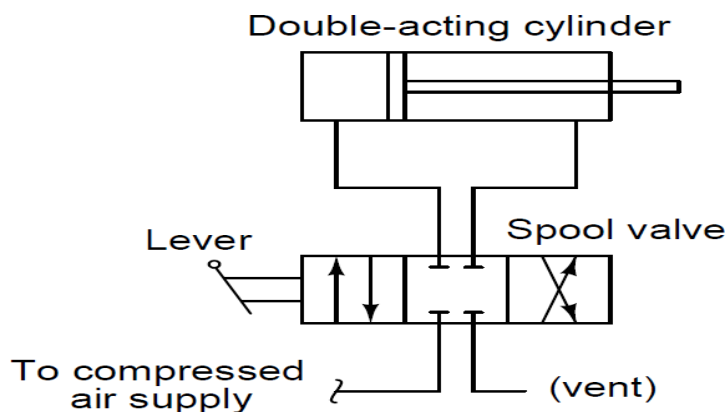
DIRECT CONTROL OF SINGLE ACTING CYLINDER

- The circuit consists of a 3/2way push button operated DCV to control a single acting cylinder.
- Initially the flow is blocked and when the push button is operated the cylinder extends and when the button is released the cylinder retracts by the compression spring located at the rod end of the cylinder.
- The adjustable flow control valves V_1 and V_2 can control the rate of extension and retraction of the cylinder.



OPERATION OF DOUBLE ACTING CYLINDER

- It is possible to achieve automatic retraction of the cylinder when the cylinder has completed its function during its extension stroke. The below circuit show such a possibility of semi-automating a cylinder.
- In the below circuit the 5/2way pilot operated DCV V_2 controls the cylinder movement. The DCV is controlled by the two push buttons V_3 and V_4 .

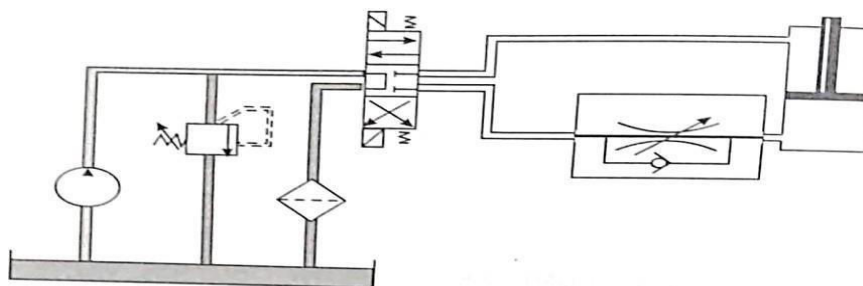


- The flow is allowed after metering through the flow control valve V_1 . When the push button V_3 is operated to spring offset position, it pilot actuates the DCV V_2 to allow the push button V_3 is operated to spring offset position, it pilot actuates the DCV V_2 to allow the compressed air to enter the piston side of the cylinder to extend.
- At the end of the extension stroke, the piston cam operates the push button V_4 . This pilot actuates the DCV V_2 to shift its position and allow the air to enter the rod side and retract the cylinder.
- Thus in application which require automatic retraction of the cylinder the above circuit design if used it is possible to achieve the control. The timing of extension and retraction can be achieved by keeping a flow control valve in the upstream of the actuator.

OPERATION OF DOUBLE ACTING CYLINDER WITH METERING IN AND METERING OUT CONTROL

Meter in circuit for extension

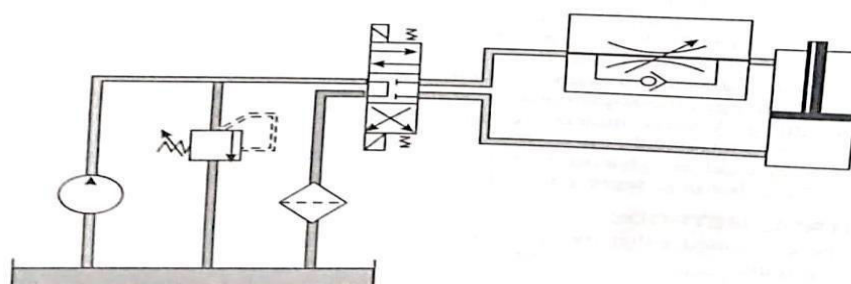
- In meter in circuit, the rate of flow of oil or air going into the cylinder is controlled by flow control valve.
- FCV is placed at inlet of the cylinder. Cap end port "C" is inlet for extension and rod end port "R" is inlet for retraction.
- In first position of 4/2 DCV air under pressure flows from P to A and B to T. this flow is through flow control valve, the flow is controlled and hence piston extension slowly.
- In second position 4/2 DCV, oil under pressure flows free from P to B and A to T. The flow is through the check valve, this is free flow. Hence the piston retracts at higher speed which is not control.



FLOW CONTROL VALVE TO CONTROL EXTENSION STROKE

Meter in circuit for retraction

- In first position of 4/2 DCV, air under pressure flows from P to A and B to T. This flow is through the check valve. This is free flow hence the piston extends at higher speed which is not controlled.
- In second position of 4/2 DCV air under pressure flows from P to B and A to T. This flow is through flow control valve. The flow is controlled and hence piston retracts slowly.
- Meter in control is used for opposing load only. It can n't prevent running away loads, because the return line from the cylinder is a free path towards reservoir. Running away load will pull the piston and piston can n't resist that.



FLOW CONTROL VALVE TO CONTROL RETURN STROKE

METER IN CIRCUITS

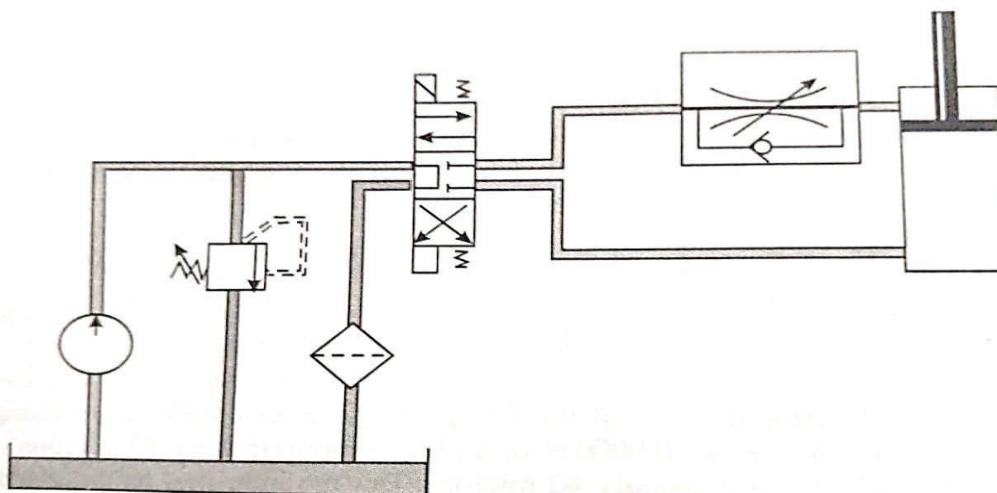
METER-OUT CIRCUIT

Meter out for extension

- In meter out circuits, the rate of flow of oil under pressure coming out of the cylinder controlled by flow control valve. FCV is placed at outlet of the cylinder. Rod end port R is outlet for extension and cap end port C is outlet for retraction.
- In first position of 4/2 DCV air under pressure flows from P to A and B to T. this flow is through the flow control valve, the flow is controlled and hence the piston extends slowly.
- In the second position 4/2 DCV, air under pressure flows from P to B and A to T. this flow is through the check valve, and free flow hence the piston retracts at higher speed which is not controlled.

Meter out for retraction

- In first position of 4/2 DCV air under pressure flows from P to A and B to T, hence the piston extends at higher speed which is not controlled.
- In second position of 4/2 DCV air under pressure flows from P to B and A to T. this flow is through flow control valve hence the flow is controlled and piston retracts slowly.
- Meter out control can be used for both opposing load as well as running away load. It can hold running away loads because there is FCV at outlet of cylinder, which maintains high pressure air at cylinder outlet.



The above circuit meters the oil coming from the Rod Side

METER-OUT CIRCUIT

Both meter-in and meter-out circuits are effective but not efficient as the excess controlled flow passes through the relief valve back to the tank.

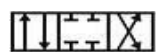
POSSIBLE SHORT QUESTION

01. What is the purpose of lubricator in FRL Unit.

Ans- lubricator is a device which mixes oil to the high velocity high pressure air so that a mist formed and lubricate all the moving parts of the pneumatic system

02. Draw 4/3 and 4/2 DCV in pneumatic system.

Ans-



3-position, 4-way, 4 ported Closed Center



2-position, 4-way, 4 ported

LONG QUESTIONS

1. Describe following pneumatic devices

Elements –filter-regulator-lubrication unit
Pressure control valves
Pressure relief valves
Pressure regulation valves
Direction control valves
3/2DCV,5/2 DCV,5/3DCV
Flow control valves
Throttle valves
ISO Symbols of pneumatic components
Direct control of single acting cylinder
Operation of double acting cylinder
Operation of double acting cylinder with metering in and metering out control

CHAPTER – 05

HYDRAULIC CONTROL SYSTEM

HYDRAULIC SYSTEM

The hydraulic system is defined as the device in which power is transmitted with the help of a fluid which may be liquid (water or oil) or a gas(air) under pressure. most of these devices are based on the principle of fluid statics and fluid kinematics.

MERITS OF HYDRAULIC SYSTEM

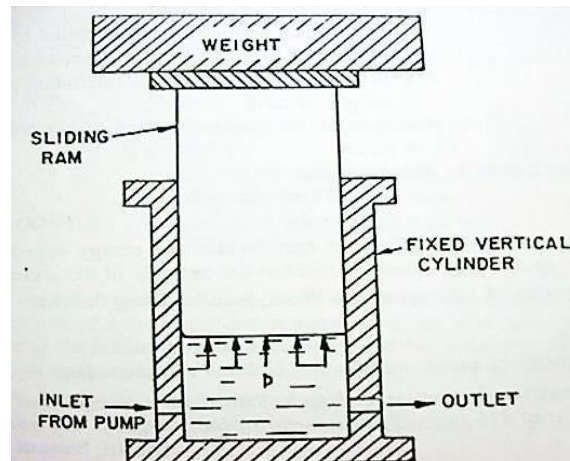
1. Small size and light weight;
2. High stiffness, high precision and fast response;
3. Large driving force, suitable for heavy load direct driving;
4. Wide speed control range and various speed control modes;
5. Self-lubrication, self-cooling and long life;
6. Easy to realize security protection.

DEMERITS OF HYDRAULIC SYSTEM

1. Poor resistance to working fluid pollution.
2. Sensitive to temperature changes.
3. Hidden danger of leakage.
4. Difficult manufacturing and high cost.
5. It is not suitable for long-distance transmission and requires hydraulic energy.

5.2 HYDRAULIC ACCUMULATORS

- The hydraulic accumulator is a device used for storing the energy of a liquid in the form of pressure energy, which may be supplied for any sudden or intermittent requirement.
- In case of hydraulic lift or the hydraulic crane, a large amount of energy is required when lift or crane is moving upward. This energy is supplied from hydraulic accumulator, but when the lift is moving in the downward direction, no large external energy is required and at that time, the energy from the pump is stored in the accumulator.
- This figure shows a hydraulic accumulator which consists of a fixed vertical cylinder containing a sliding ram. A heavy weight is placed on the ram.
- The inlet of the cylinder is connected to the pump, which continuously supplies water under pressure to the cylinder. The outlet of the cylinder is connect is connected to the machine (which may be lift or crane etc.)
- The ram is at the lower most position in the beginning. The pump supplies water under pressure continuously. If the water under pressure is not required by the machine (lift or crane), the water under pressure will be stored in the cylinder.
- This will raise the ram on which a heavy weight is placed. When the ram is at the uppermost position, the cylinder is full of water and accumulator has stored the maximum amount of pressure energy. When the machine (lift or crane) requires a large amount of energy, the hydraulic accumulator will supply this energy and ram will move in the downward direction



CAPACITY OF HYDRAULIC ACCUMULATOR

It is defined as the maximum amount of hydraulic energy stored in the accumulator. The expression for the capacity of accumulator is obtained as,

Let A = Area of the sliding ram

L = Strokes or lift of the ram

P = intensity of water pressure supplied by the pump

W = Weight placed on the ram

W = Intensity of pressure \times Area of ram

Then $p \times A$

The work done in lifting the ram = $W \times$ lift of ram = WL

$$= p \times A \times L$$

The work done in lifting the ram is also the energy stored in the accumulator and energy stored is equal to the capacity of the accumulator.

Capacity of the accumulator = work done in lifting the ram

$$= p \times A \times L$$

But $A \times L$ = volume of accumulator

Capacity of accumulator = $p \times$ volume of accumulator

PRESSURE CONTROL VALVE

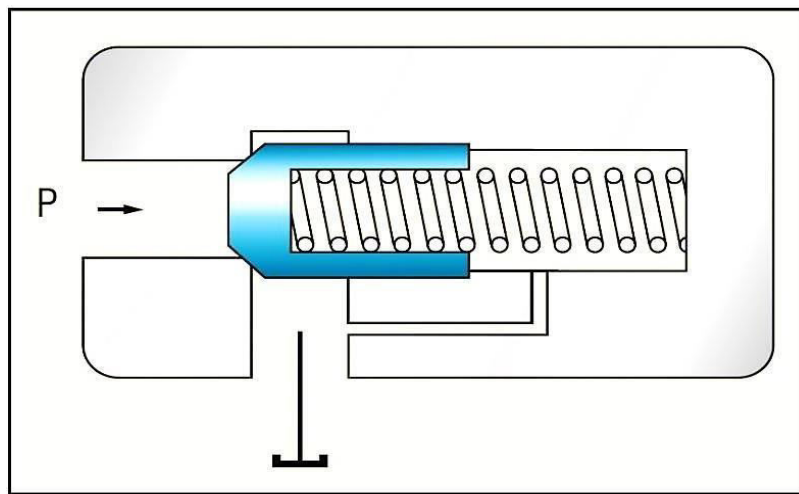
- Pressure-control valves are found in virtually every hydraulic system, and they assist in a variety of functions, from keeping system pressures safely below a desired upper limit to maintaining a set pressure in part of a circuit.

- Types include relief, reducing, sequence, counterbalance, and unloading. All of these are normally closed valves, except for reducing valves, which are normally open.

RELIEF VALVES

- Most fluid power systems are designed to operate within a pre-set pressure range. This range is a function of the forces the actuators in the system must generate to do the required work. Without controlling or limiting these forces, the fluid power components (and expensive equipment) could be damaged. Relief valves avoid this hazard. They are the safeguards which limit maximum pressure in a system by diverting excess oil when pressures get too high.
- Relief valves are either direct-acting or pilot-operated.

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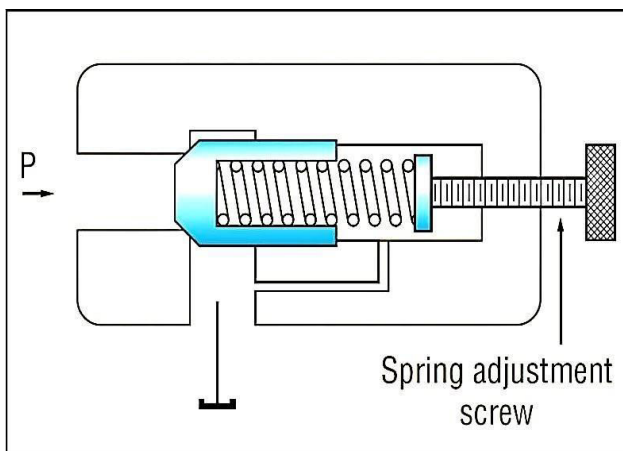


- Figure 1. Simple, direct-acting relief valve has no adjusting screw and therefore opens at a fixed, pre-set pressure as controlled by setting of compression spring.
- A direct-acting valve may consist of a poppet or ball, held exposed to system pressure on one side and opposed by a spring of pre-set force on the other. In a fixed, non-adjustable, normally closed relief valve, Figure 1, the force exerted by the compression spring exceeds the force exerted by system pressure acting on the ball or poppet. The spring holds the ball or poppet tightly seated. A reservoir port on the spring side of the valve returns leakage fluid to tank.
- When system pressure begins to exceed the setting of the valve spring, the fluid unseats the ball or poppet, allowing a controlled amount of fluid to bypass to reservoir, maintaining system pressure at the valve setting. The spring re-seats the ball or poppet when enough fluid is released (bypassed) to drop system pressure below the setting of the valve spring.
- Because the usefulness of a fixed relief valve is limited to the single setting of its spring, most relief valves are adjustable. This is commonly achieved with an adjusting screw acting on the spring, Figure 2. By turning the screw in or out, the operator compresses or decompresses the spring respectively. The valve can be set to open at any pressure within

a desired range. Aside from the adjustable feature, this valve works just like the fixed valve in Figure 1.

- Spring-loaded poppet valves are generally used for small flows. They don't leak below cracking pressure and respond rapidly, making them ideal for relieving shock pressures. They often are used as safety valves to prevent damage to components from high surge pressures, or to relieve pressure caused by thermal expansion in locked cylinders. The differential between cracking and full open pressure on spring-loaded poppet relief valves is high. For this reason they are not recommended for precise pressure control.

5.2.2 PRESSURE RELIEF VALVE



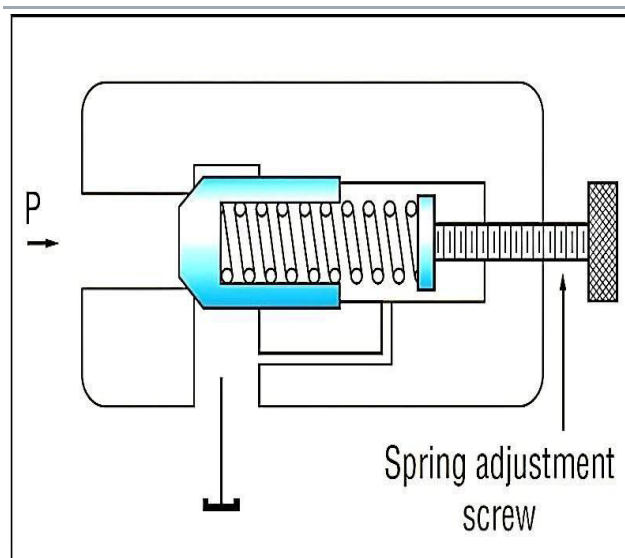
- direct-acting relief valve blocks flow through the valve until force of system pressure on the poppet overcomes the adjustable spring force and downstream pressure.
- Relief valves are also made to relieve flow in either direction. Fluid pressure at the other port acts on a shoulder on the plunger to open the valve. Another type of direct-acting relief valve has a guided piston. In this valve a sliding piston, instead of a poppet, connects the pressure and reservoir ports. System pressure acts on the piston and moves it against a spring force. As the piston moves, it uncovers a reservoir port in the valve body.
- These valves have a fast response but may be prone to chatter. They can be damped to eliminate chatter, but this also slows their reaction time. They are reliable and can operate with good repetitive accuracy if flow does not vary widely. Valves with hardened-steel pistons and sleeves have a very long service life. They may leak slightly below cracking pressure unless the pistons are sealed.
- A variation of the guided-piston relief valve is the differential-piston relief valve. Here, the pressure acts on an annular area (the difference between two piston areas). This annular area is smaller than the valve's seat area. This permits the use of a lighter spring than would be needed if pressure acted on the entire seat area. These valves have a lower pressure differential than poppet or guided-piston relief valves.

5.2.3 PRESSURE REGULATION VALVES

- A pressure regulator is a valve that controls the pressure of a fluid or gas to a desired value. Regulators are used for gases and liquids, and can be an integral device with a pressure setting, a restrictor and a sensor all in the one body, or consist of a separate pressure sensor, controller and flow valve
- There are two types of pressure regulation valve-: The pressure reduction regulator and the back-pressure regulator.
- A pressure reducing regulator is a control valve that reduces the input pressure of a fluid or gases to a desired value at its output. It is a normally-open valve and is installed upstream of pressure sensitive equipment.
- A back-pressure regulator or back-pressure valve, is a control valve that maintains the set pressure at its inlet side by opening to allow flow when the inlet pressure exceeds the set value.
- It is a normally-closed valve which may be installed in parallel with sensitive equipment or after the sensitive equipment to provide an obstruction to flow and thereby maintain upstream pressure.
- Both types of regulator use feedback of the regulated pressure as input to the control mechanism, and are commonly actuated by a spring loaded diaphragm or piston reacting to changes in the feedback pressure to control the valve opening, and in both cases the valve should be opened only enough to maintain the set regulated pressure.

PRESSURE REDUCING VALVE

- A pressure reducing regulator's primary function is to match the flow of gas through the regulator to the demand for gas placed upon it, while maintaining a sufficiently constant output pressure.



If the load flow decreases, then the regulator flow must decrease as well. If the load flow increases, then the regulator flow must increase in order to keep the controlled pressure from decreasing due to a shortage of gas in the pressure system. It is desirable that the controlled pressure does not vary greatly from the set point for a wide range of flow rates

but it also desirable that flow through the regulator is stable and the regulated pressure is not subject to excessive oscillation.

Schematic diagram of pressure reducing regulator (A) and back-pressure regulator (B).

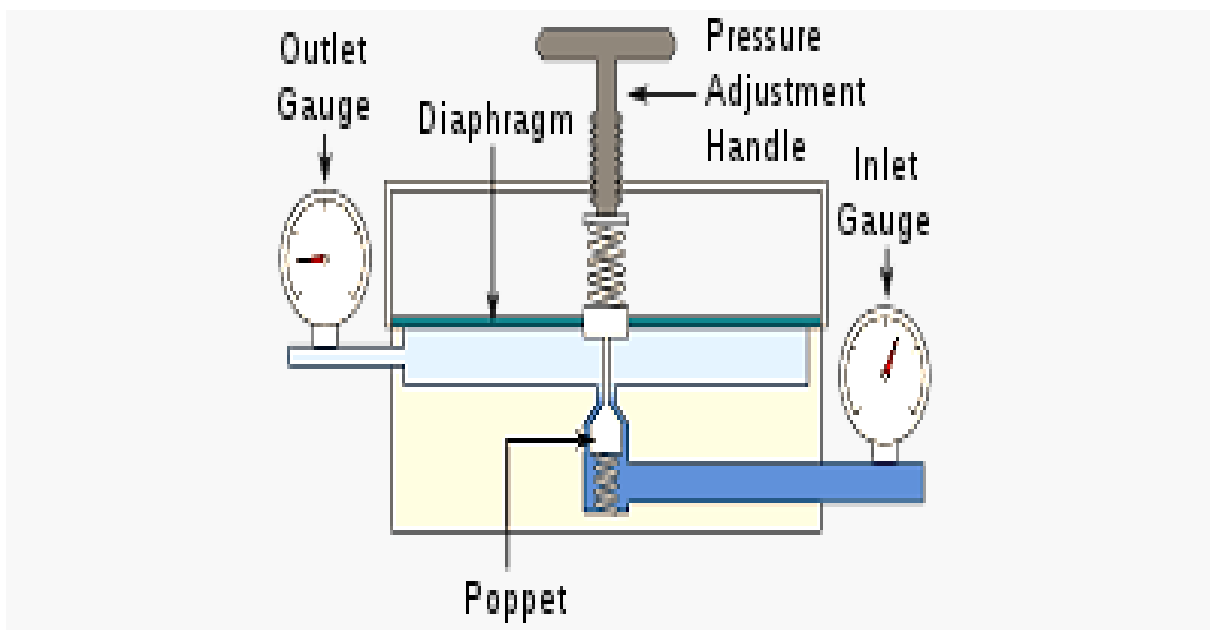
➤ The upper diagrams show the normal state for the valves, which is normally open for pressure reducers and normally closed for back-pressure valves.

- 1. Pressure setting screw
- 2. Spring
- 3. Actuator
- 4. Inlet port (high pressure)
- 5. Outlet port (low pressure)
- 6. Valve body
- 7. Valve crown and seat

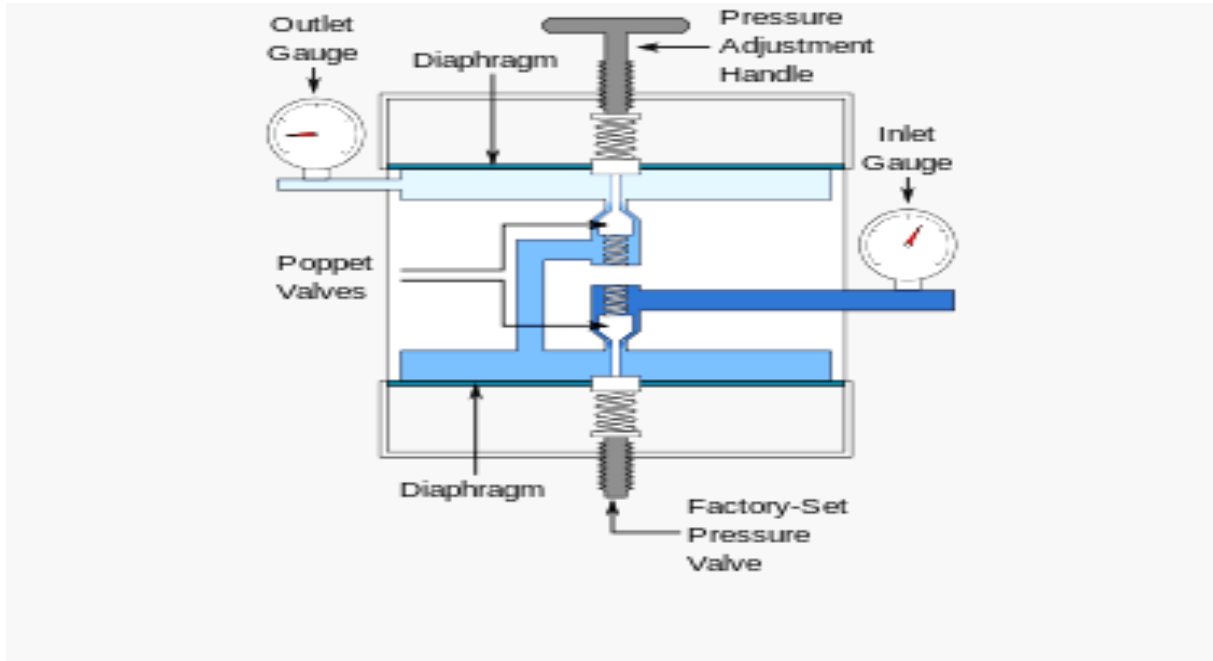
A pressure regulator includes a restricting element, a loading element, and a measuring element:

- The restricting element is a valve that can provide a variable restriction to the flow, such as a globe valve, butterfly valve, poppet valve, etc.
- The loading element is a part that can apply the needed force to the restricting element.
- This loading can be provided by a weight, a spring, a piston actuator, or the diaphragm actuator in combination with a spring.
- The measuring element functions to determine when the inlet flow is equal to the outlet flow. The diaphragm itself is often used as a measuring element; it can serve as a combined element.

SINGLE STAGE REGULATOR



DOUBLE STAGE REGULATOR



DIRECTION CONTROL VALVES

As the name implies directional control valves are used to control the direction of flow in a hydraulic circuit. They are used to extend, retract, position or reciprocate hydraulic cylinder and other components for linear motion.

Valves contains ports that are external openings for fluid to enter and leave via connecting pipelines, The number of ports on a directional control valve (DCV) is usually identified by the term“way”. For example, a valve with four ports is named as four-way valve.

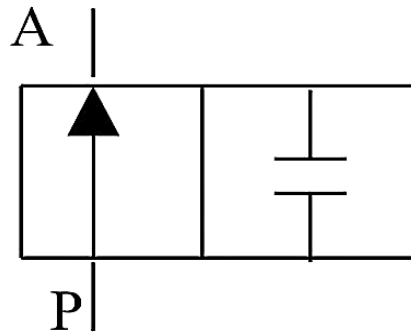
Directional control valves can be classified in a number of ways:

1. According to type of construction:
 - Poppet valves
 - Spool valves
 2. According to number of working ports:
 - Two- way valves
 - Three – way valves
 - Four- way valves.
 3. According to number of Switching position:
 - Two – position
 - Three – position
 4. According to Actuating mechanism:
 - Manual actuation
 - Mechanical actuation
 - Solenoid (Electrical) actuation
 - Hydraulic (Pilot) actuation
- Pneumatic actuation

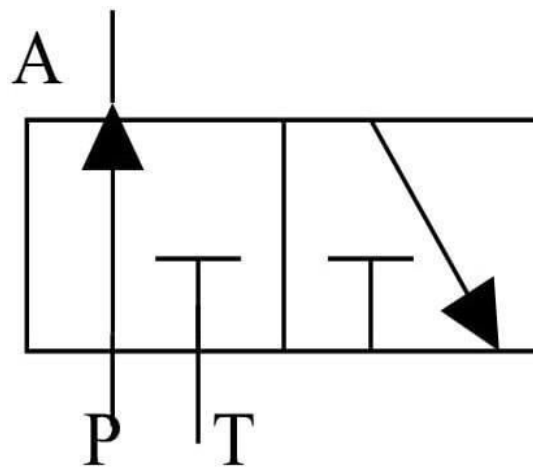
- Indirect actuation

The designation of the directional control valve refers to the number of working ports and the number of switching positions.

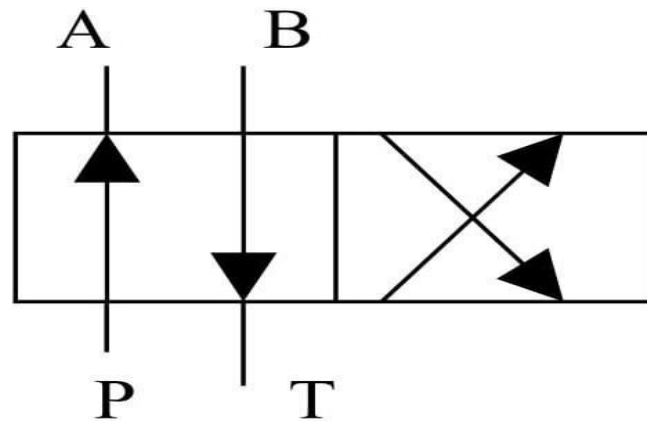
Thus a valve with 2 service ports and 2 switching positions is designated as 2 / 2 way valve.



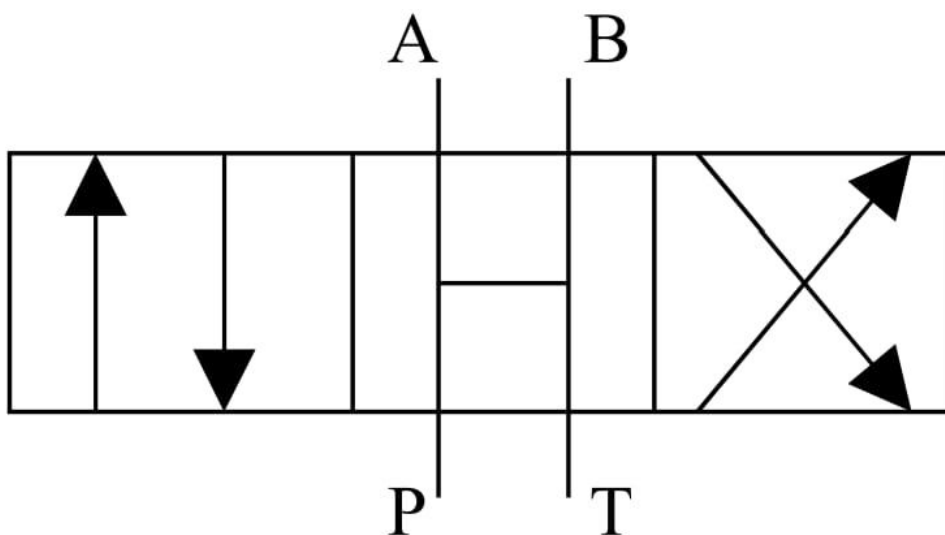
A valve with 3 service ports and 2 position is designated as 2 / 3way valve



A valve with 4 service ports and 2 position is designated as 2 / 4 valve.



A valve with 4 Service ports and 3 Switching position is designated as 3 / 4way valve



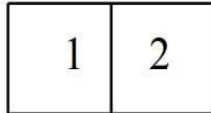
A valve with 2 spool position is shown and also a valve with 3 spool positions. In directional control valves with 3 spool position, the central position is the neutral position (or mid position or zero or null position). The neutral position is the position in which the moving parts are assumed to be inactive, but affected by a force (e.g. spring)

The ports are designated as follows:

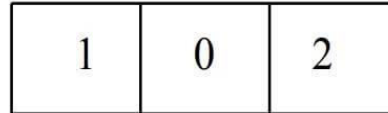
P = Pressure Port (Pump Port)

T = Tank Port

A, B = User Ports



2- Position valve



3- Position valve

FLOW CONTROL VALVE

Flow control valves are used to regulate the flow rate and pressure of liquids or gases through a pipeline. Flow control valves are essential for optimizing system performance, relying on a flow passage or port with a variable flow area.

Function of Hydraulic Flow Control Valve

The purpose of a flow control valve is to regulate the flow rate in a specific portion of a hydraulic circuit. In hydraulic systems, they're used to control the flow rate to motors and cylinders, thereby regulating the speed of those components.

Hydraulic flow control valves also control the rate of energy transfer at a given pressure. This is based on the physics concept surrounding work, energy and power.

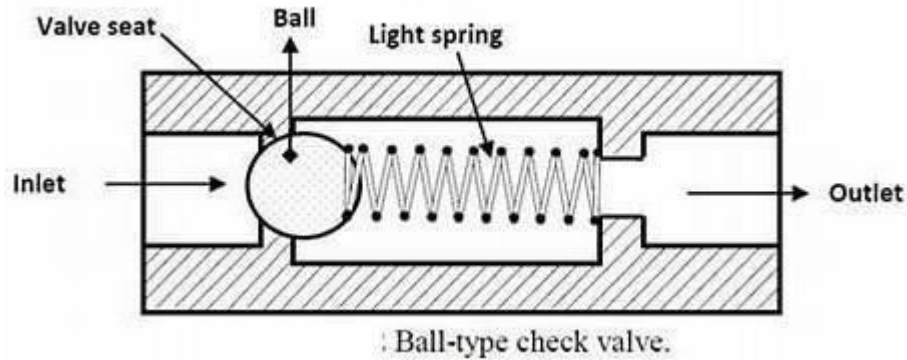
The energy transfer must be equal to the total work done. Because the actuator speed determines the rate of energy transfer, speed is a function of the flow rate. Directional control valves serve a different purpose, directing the energy transfer system to the appropriate location at the appropriate time, although some pressure and flow rate control may be achieved using directional control valves, as they can throttle the flow of fluid.

There are a variety of flow control valve designs, with most intended for specific applications. Therefore, understanding how hydraulic flow control valves work is crucial in selecting the right valve for an application.

The most common types of flow control valves include:

- Ball
- Diaphragm
- Needle
- Butterfly
- Plug

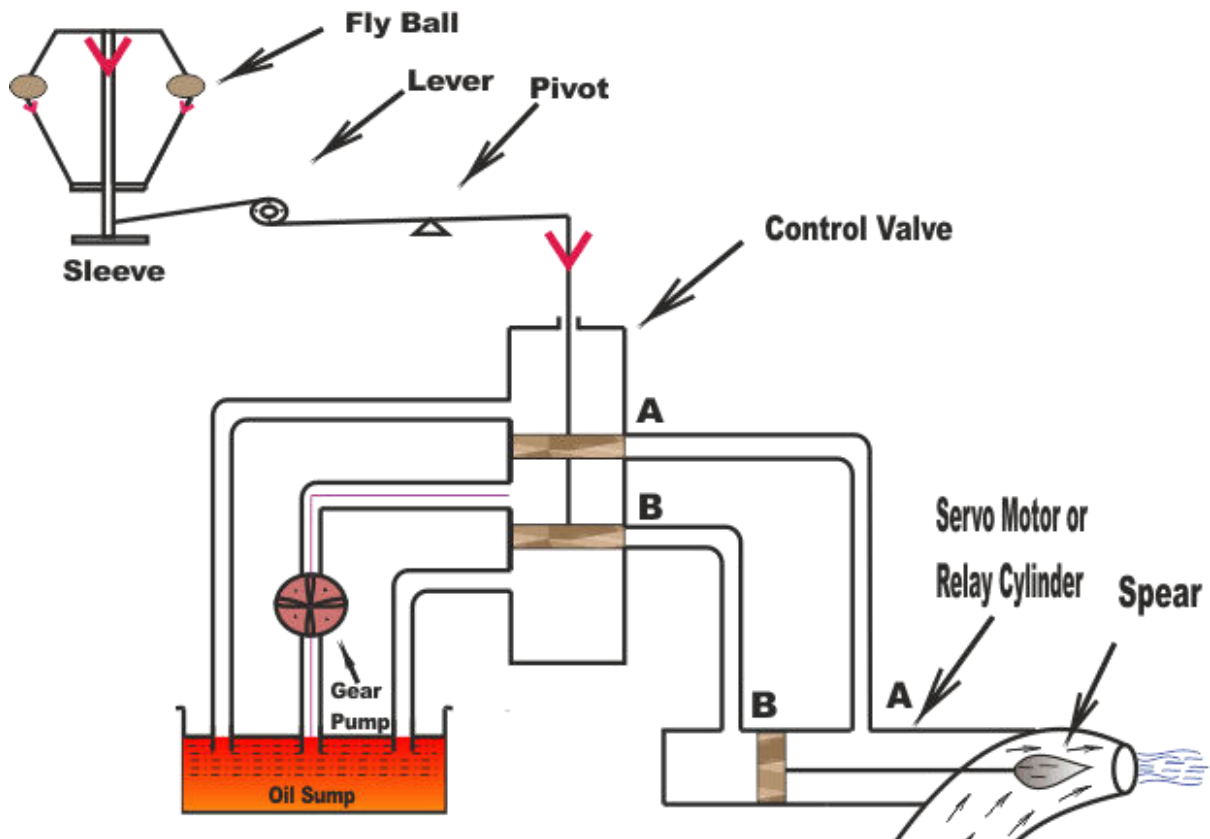
The simplest flow control valves have an aperture which opens or closes in order to increase or slow down the flow rate. Ball valves are among the simplest options, consisting of a ball attached to a handle. The ball has a hole through the centre, and when the handle is turned, the hole is aligned with valve openings in order to permit flow. In order to shut off the flow, the handle is used to turn the hole perpendicular to the valve openings, which obstructs the flow.



Other valve types function in a similar way with some mechanism for either permitting or blocking flow. A butterfly valve, for instance, has an internal metal plate attached to a turning mechanism. The plate opens or closes when the mechanism is turned. Needle valves, which are among the more precise valve options, have an adjustable needle and a valve stem which restricts or allows the flow of liquid. The needle can be adjusted to block the flow of fluid completely, allow the free flow of liquid, or partially obstruct the flow to varying degrees, therefore allowing for greater and more precise control over the flow rate.

5.3.3 THROTTLE VALVE

- Throttle Governing of steam Turbine is most popular and easiest way to control the turbine speed. When steam turbine controls its output speed by varying the quantity of steam entering the turbine is called Throttle Governing. It is also known as Servomotor methods.
- In this system, a centrifugal governor is driven from the main shaft of turbine by belt or gear arrangement.
- A control valve is used to control the direction of oil flow which supplied by the pipe AA or BB.
- The servomotor or relay valve has a piston which moves towards left or right depending upon the pressure of oil flow through the pipes AA or BB. This cylinder has connected a needle which moves inside the nozzle.
- When the turbine is running at normal speed, everything in the turbine such as such control valve, servomotor, piston position, fly balls of centrifugal governor will be in their normal position as shown in the figure. The mouth of both pipes AA or BB is closed into the control valves.
- Assume that the turbine's load increases. It will decrease its speed which will decrease the centrifugal force of the turbine.
- Now fly balls of the governor will come down thus decreasing their amplitude. These fly balls also bring down the sleeve. The sleeve is connected to a control valve rod through a lever pivoted on the fulcrum. This down word sleeve will raise the control valve rod.
- Now oil is coming from the from the oil sump, pumped by gear pump is just stay at the mounts of both pipes AA or BB which are closed by the two wings of control valves. So, raise of control valve rod will open the mouth of the pipe AA but BB is still closed.
- Now the oil pressure is coming from the pipe AA. This will rush from the control valve which will move the right side of the piston. As a result, the steams flow rate into the turbine increases which will bring the speed of the turbine to the normal range. When speed of the turbine will come to its normal range, fly balls will come into its normal position. Now, sleeve and control valve rod will back to its normal position.



FLUID POWER PUMPS

The pumps are the heart of the hydraulic system. Pumps transfer the mechanical energy they receive from the prime mover (electric motor) into fluid energy.

PUMPING THEORY:

All pumps operate on the principle that a partial vacuum is created at the inlet of the pump due to internal operation of the pump. This allows atmospheric pressure to push the fluid out of the reservoir and into the pump intake. The pump then mechanically pushes the fluid out into the discharge line.

PUMP CLASSIFICATION

There are two types of Pump

- (1) Positive displacement pumps
- (2) Non positive displacement pumps

Positive displacement pumps

Ex – Rotary pumps (gear, screw, lobe), Reciprocating pump (Radial, inline, axial type)

Non positive displacement pumps

Ex – Centrifugal pumps (impeller type), Axial pump (propeller type)

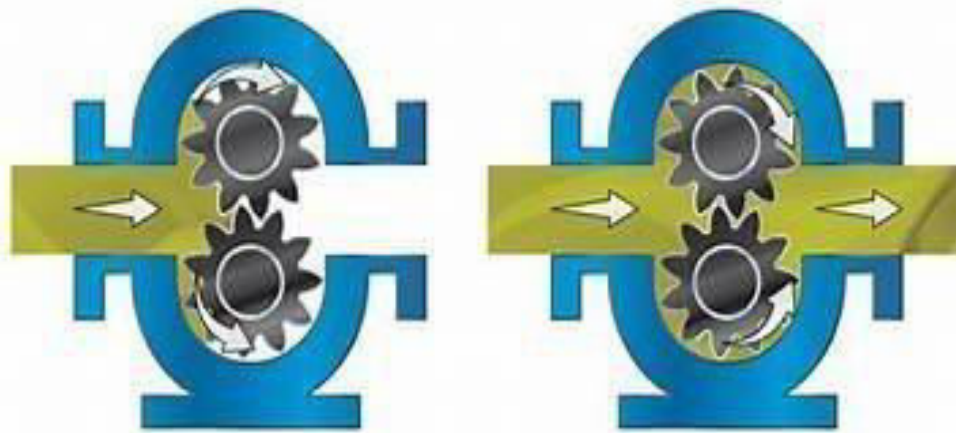
5.4.1 GEAR PUMP: (external & internal gear pump)

There are two types of gear pumps-

- (1) External gear pumps
- (2) Internal gear pumps

EXTERNAL GEAR PUMPS

External gear pumps are the most popular hydraulic pumps in low-pressure ranges due to their long operating life, high efficiency and low cost. They are generally used in a simple machine. The most common form of external gear pump is shown in Figs.



They have meshing gears of equal size. The drive gear is coupled with the drive shaft of the electric motor. This gear drives the other gear. As they rotate the fluid is trapped and carried between teeth of the driver and driven gears and external casing, which is in close contact with the gears. The pump creates flow and as they pass through the components of the systems, pressure is generated and transmits it to flow and as they pass through the components of the systems, pressure is generated and transmits it to the actuator. the displacement of the gear pump increases with an increase in input rpm.

VOLUMETRIC DISPLACEMENT AND THEORITICAL FLOW RATE

Let D_o = addendum circle diameter of the gear teeth,

D_i = base circle diameter of the gear

W = width of the gear

N = speed of the prime mover

Q_t = theoretical pump flow rate

V_D = displaced volume of the pump

Volumetric displacement $V_D = \pi/4 (D_o^2 - D_I^2) W \text{ mm}^3$

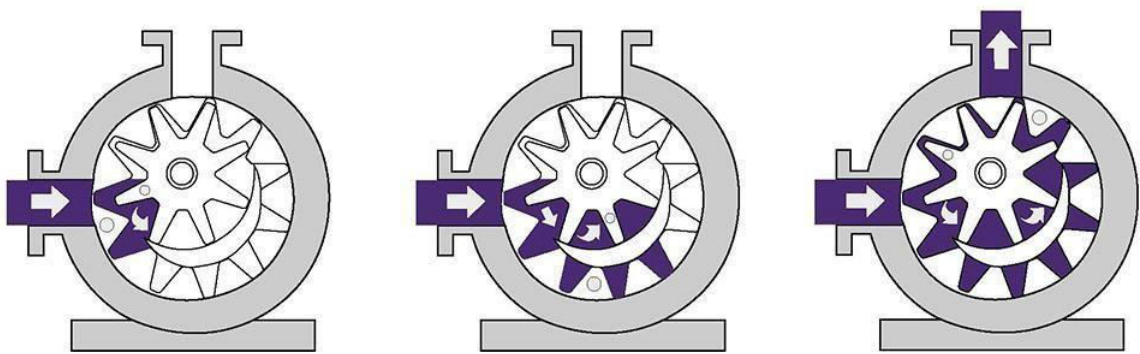
Theoretical flow rate $Q_t = V_D N \text{ mm}^3/\text{min}$

Volumetric efficiency, $\eta_v = \text{actual discharge} / \text{theoretical discharge}$

$$= Q_A/Q_T \times 100$$

The high pressure are created when a large load or resistance to flow is encountered. The actual discharge depends on the discharge pressure. As the discharge pressure increases the amount of internal leakage increases thus decreasing pump outlet volume. Hence the pump should be operated at pressure less than the pressure, which will cause mechanical damage to the pump.

INTERNAL GEAR PUMP



In this type of gear pump both the gear rotate in same direction. As the gears move away near the inlet, the oil is trapped in the gear space and travels around the crescent seal and near the outlet as the two gears come closer pressure rises and the oil is pushed into the outlet port.

5.4.2 VANE PUMP

There are two types of vane pump. They are-

Unbalanced vane pump

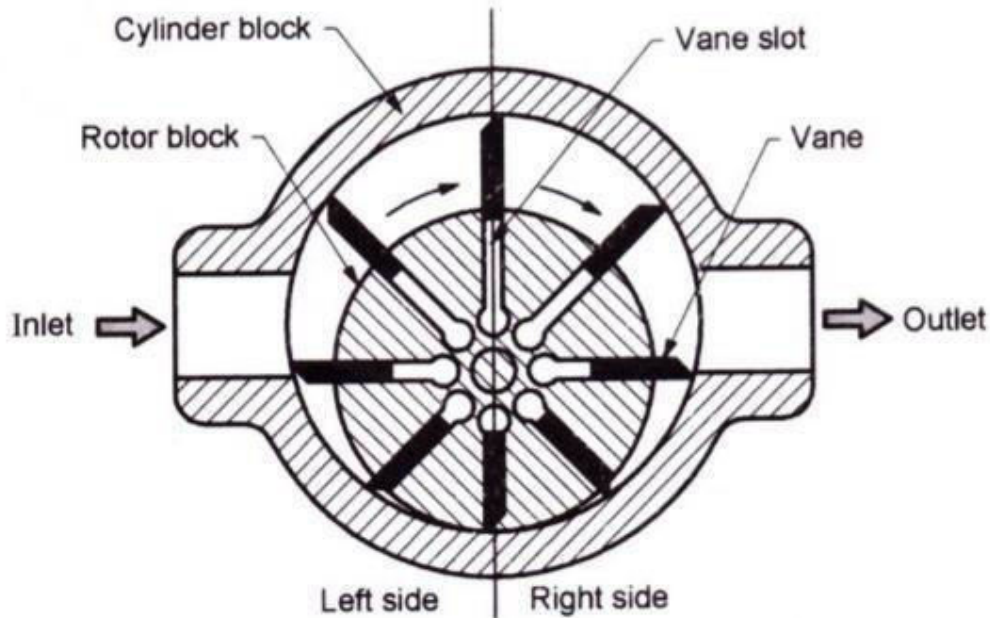
Balanced vane pump

UNBALANCED VANE PUMP

The unbalanced vane pumps have a rotor connected to the rotating shaft which is coupled with the prime mover. The rotor has radial slots into which there are vanes that that move in and out while rotating due to centrifugal force. The cam ring is circular in shape, which limits the outward movement

of the rotors. At inlet the vanes move out creating the suction of fluid and as they rotate the fluid travels entrapped between the radial vanes and the cam ring. Nearing the outlet the vanes are pushed in by the cam ring resulting in high pressure. This results in pushing or discharge of liquids out into the discharge line.

Unbalanced Vane Pump :



Ajaypalsinh Barad

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Advantages:

The advantage of the unbalanced vane pump is that as the eccentricity between cam ring and rotor is changed the volume of fluid pumped can be proportionately changed.

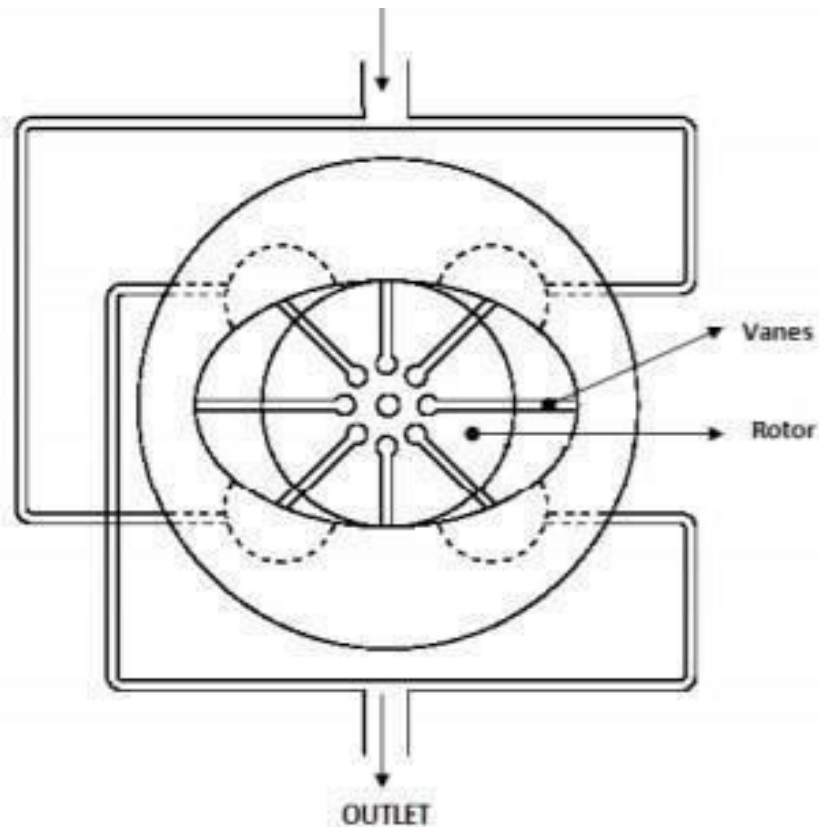
Disadvantages:

The suction side of the fluid is at atmospheric pressure. but at the discharge end the fluid is at system pressure and as a result it imparts the side axial thrust on the rotor. This unbalanced force creates changes in the displacement volume and failure of the rotor.

BALANCED VANE PUMP

- The disadvantage of the unbalanced vane pump is that it experiences axial thrust. Changing the shapes of the cam ring elliptical instead of circular can eliminate side thrust. In addition if there are two suction and discharge ports placed at equal and opposite quadrants, the two pressure or discharge port cancel out their forces and thus side thrust is eliminated.
- The displacement of fluid and the basic operation of the pump are similar to the unbalanced pump except that there are two suction and discharge pressure. the pump remains a constant volume discharge pump and hence they cannot be used as a variable

discharge pump. But most of the industrial application use only constant volume positive displacement balanced vane pumps.



Operation of a balanced vane pump

PISTON PUMP

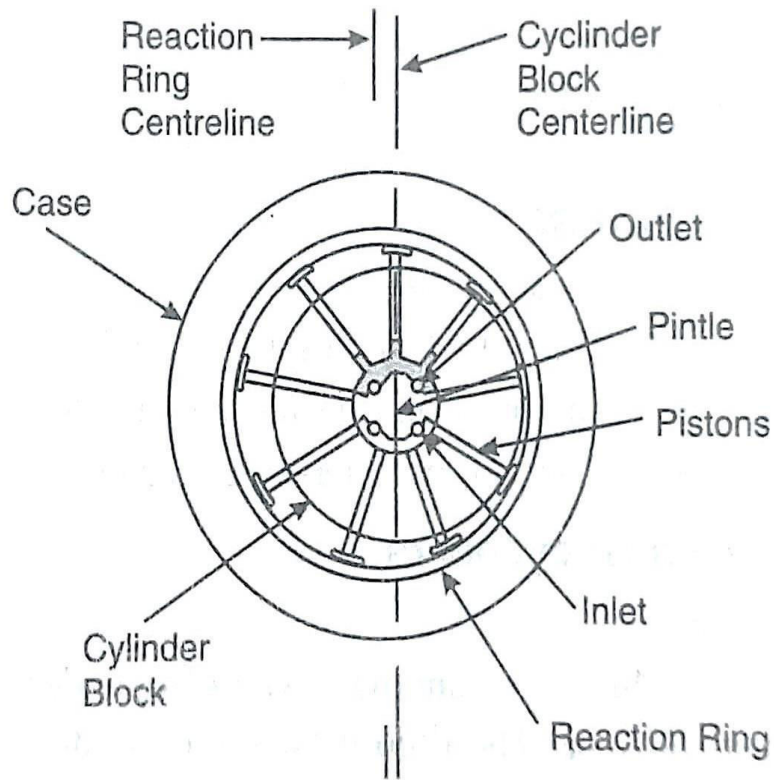
The piston pumps are reciprocating pumps. they are broadly classified as-

- (1) Axial piston pump
- (2) In line piston pump
- (3) Radial piston pump

RADIAL PISTON PUMP

- In this type the piston remains in contact with the reaction ring due to centrifugal force and back pressure on the pistons.
- To provide pumping action, the reaction ring moves eccentrically with respect to the pintle or shaft axis. As the cylinder barrel rotates, the piston on one side move out. This draws fluid as each cylinder passes the maximum port.
- When the piston moves to maximum eccentricity, it is forced back by the reaction ring. This forces the fluid into the discharge port of the pintle.

Operation of a radial piston pump



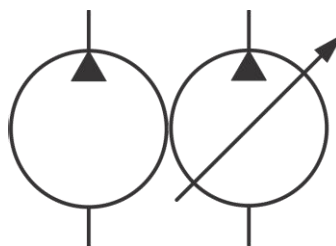
5.5 ISO SYMBOLS FOR HYDRAULIC COMPONENT

Hydraulic Reservoir

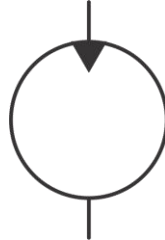


A hydraulic reservoir stores hydraulic fluid. This is a must-have component in any hydraulic system. All hydraulic reservoirs are open to the atmosphere except in the case of those used in aircraft and submarines.

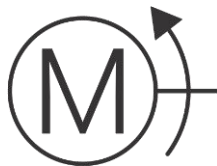
Hydraulic Pump and Motor



A hydraulic pump converts electrical and/or mechanical energy into hydraulic energy. The lower end (suction side) of a pump is connected to the hydraulic reservoir, the upper end is connected to the remaining circuit. The dark upper triangle in these hydraulic symbols indicates fluid going out of the system and hence represents a pump.



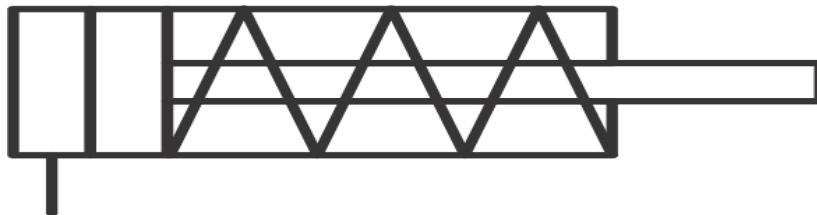
In the case of the hydraulic motor, the dark triangle is inverted indicating that the fluid is entering into the system. A hydraulic motor converts hydraulic energy into mechanical energy.



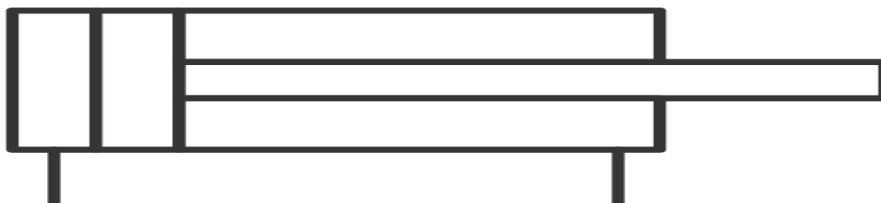
System output is represented by an arrow at 450 – this can be adjusted, In other words, that the pump/motor can deal with variable flow rate per shaft rotation. Most industrial applications use electric motors as prime movers to rotate hydraulic pumps. The electric motor is represented by the letter M inside of a circle. The curved arrow represents the direction of shaft rotation.

Hydraulic Cylinders

Hydraulic cylinders can be categorized as single acting cylinders and double acting cylinders.

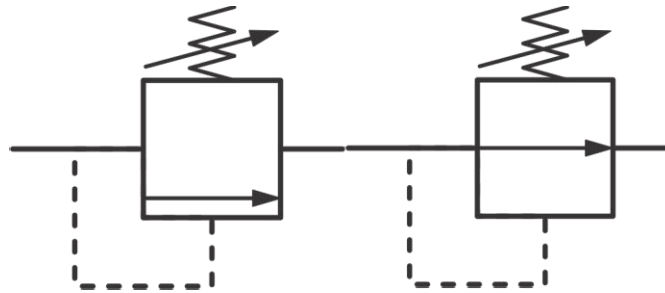


Single acting cylinders can perform operations in only one direction and return to the initial position by spring.



Double acting cylinders can actuate in either direction depending upon the position of the direction control valve

Controlling valves



Pressure Relief Valve

A pressure relief valve is a NC (normally closed) type safety valve which operates when system pressure increases above a maximum working pressure. The normally closed position is indicated by the arrow away from the centre line. The dashed line indicates that the system pressure acts against spring force for valve actuation.

5.6 ACTUATORS

The actuators are the devices, which convert the hydraulic energy into mechanical energy. The high pressurised fluid when passes through the actuator converts the fluid energy into linear or rotary motion. When it converts the energy into reciprocating motion they are termed as cylinders and when they rotate and produce torque they are named as motors.

CYLINDERS

1. These are linear actuators
2. The output motion is straight line
3. The hydraulic power is converted into linear mechanical power.
4. They are used basically for pushing, pulling, tilting and pressing.

Types of cylinder

Ram: this is the simplest type of cylinder. Usually these cylinders are vertical type. The fluid is passed on bottom side of the cylinder to push up and do work. The retraction of the cylinder

is achieved by gravity. It has only one fluid chamber and the application is on the other side of the ram. It can carry heavy load and has a large stability on heavy load.

Single acting cylinder:

This cylinder type has one fluid chamber and may be placed either vertical or horizontal or at any position. The fluid is pressurised on the piston side and on the rod side it is pushed by the spring.

The fluid pushed the piston out to do work and it retract by the spring force.

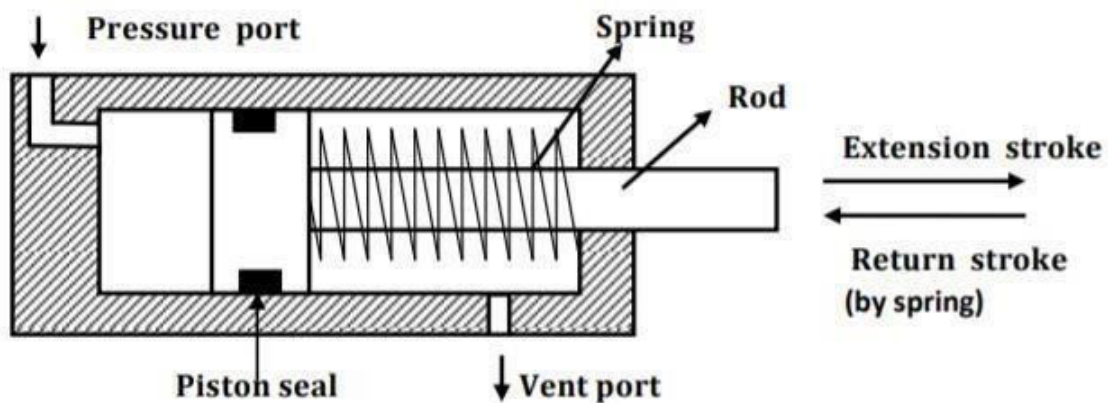


Figure 1.1 Single-acting cylinders

Double acting cylinder

- This cylinder type has two fluid chambers and both the extension and return of the cylinder is by the fluid power. These are also called as differential cylinder.
- The pressure is applied on both the sides of the piston. The volume on both the side of the piston are different.
- The volume on the piston side is more and on the rod side the rod area reduces the actual area and thus the area, which carries the fluid pressure, is less on the rod side. This results in different pressure levels on either side and is called as differential cylinders.

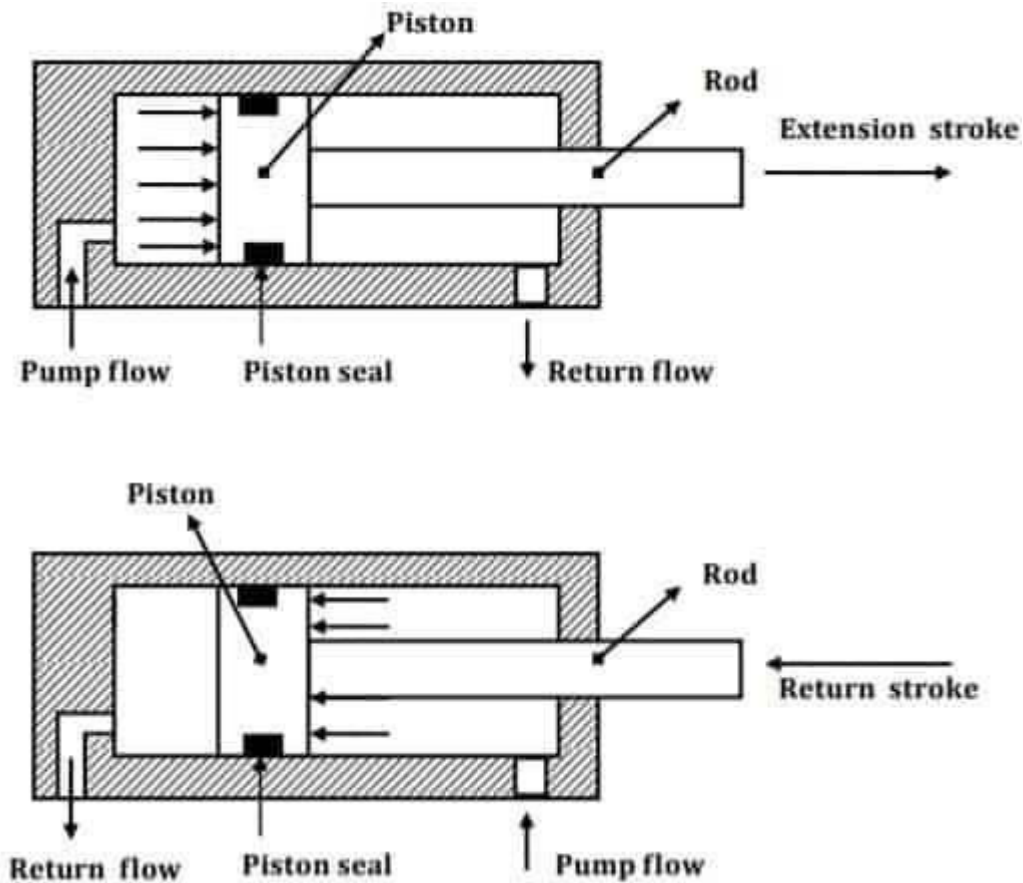


Figure 1.4 Double-acting cylinder with a piston rod on one side

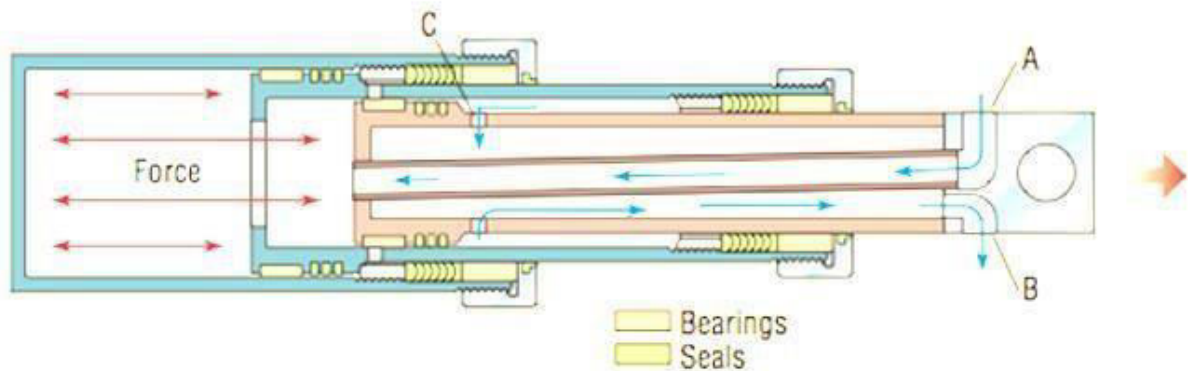
Double rod cylinder

This cylinder type also has two fluid chambers and both the extension and return of the cylinder is by the fluid power. These are called as non-differential cylinders. The pressure is applied on both the side of the piston. The volume and area on both the side of the piston are equal. Equal force can be generated in both extension /return strokes. These cylinders are used when equal force and equal speed on both the strokes are required.

Telescopic cylinders

These cylinders are used in application, which require a lengthy operation. Some of the applications of this type are the ones used in automobiles to lift the chassis to unload the vehicle. The extension of these type of cylinders occurs one after the other.

Extension of a double-acting telescopic cylinder



MOTORS:

1. These are called rotary actuators.
2. This construction is similar to the pump construction.
3. Their functionality is just reverse of the pumps.
4. Their principle of operation is instead of pushing the fluid as pumps, pressurized fluid push the internal surface area that develops torque and rotation.
5. Both the input and output are pressurized and hence most of the motors are internally drained.
6. The most common motors are
 - (a) Gear motors
 - (b) Vane motors
 - (c) Piston motors
 - (d) Bent axis piston motors
7. The motors are rated based on the displacement and torques generated.

8. Large displacement and large radius motors produce more torque.

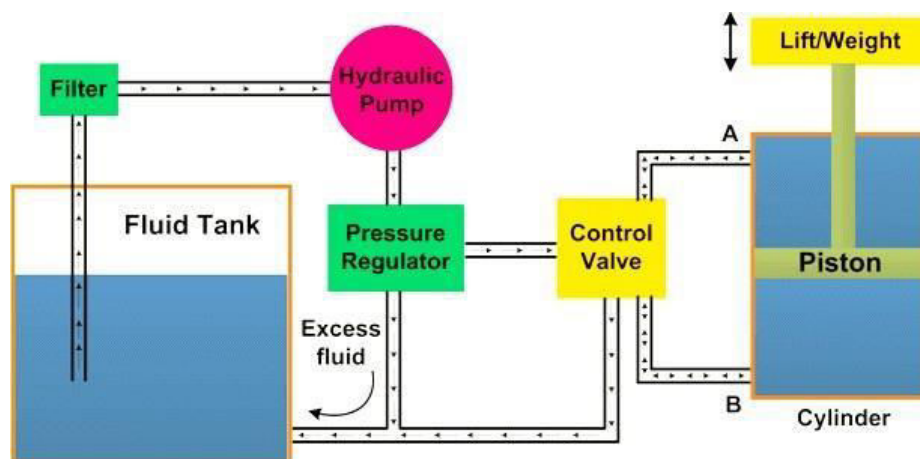
$$\text{Torque} = \text{force} \times \text{radius}$$

For same pressure, if the radius of the motors, internal component is increased, then can produce large torque.

5.7 HYDRAULIC CIRCUITS:

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 consist 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
 - hydraulic pump
 - pressure regulator
 - control valve
 - leak proof closed-loop piping
- 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.

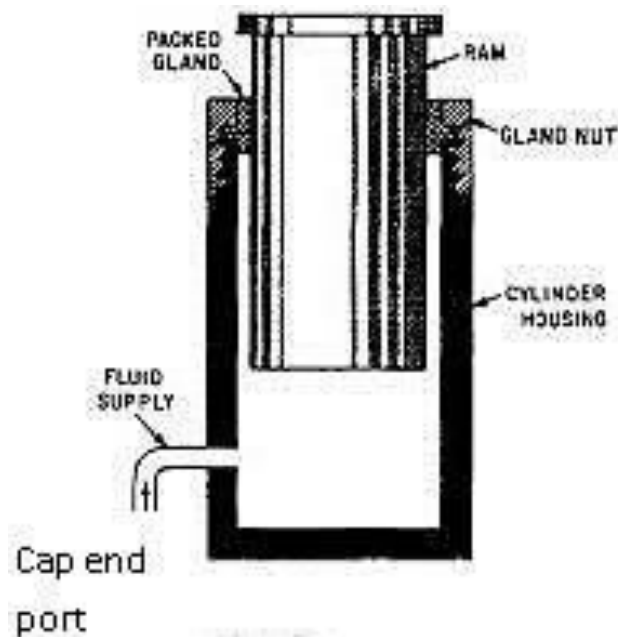
Components of Hydraulic System

Basic hydraulic system has the following components:

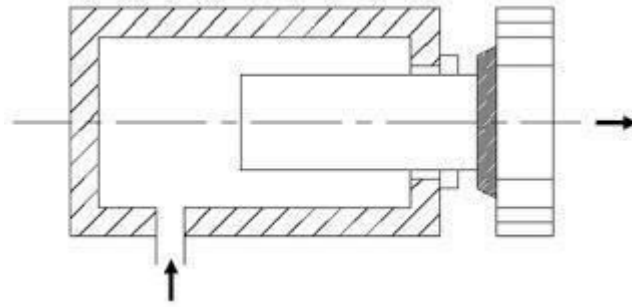
- 1) Oil reservoir
- 2) Rotary pump
- 3) Pressure relief valve
- 4) Direction control valve
- 5) Flow control valve
- 6) Double-acting cylinder
- 7) Pressure gauge
- 8) Filter

DIRECT CONTROL OF SINGLE ACTING CYLINDER

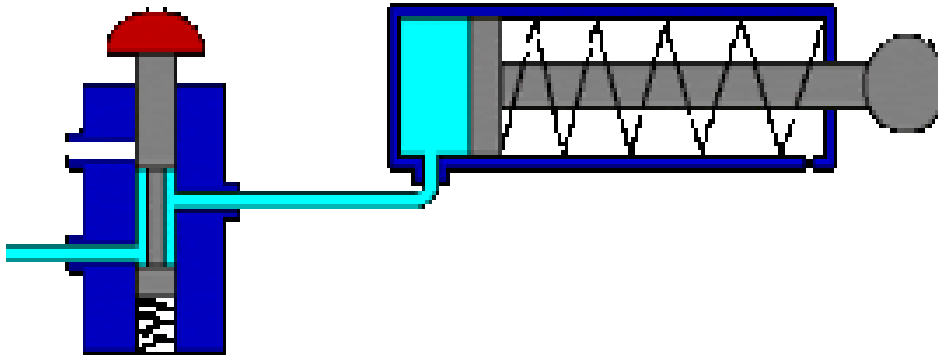
- Single acting hydraulic cylinders are the simplest form of hydraulic cylinder which is used for pulling, lifting, moving and holding the load. Single acting cylinder, as shown in figure, will have one port i.e. cap end port. Single acting cylinder, as name indicates, will be operated hydraulically in one direction only.
- Single acting hydraulic cylinder will have one piston within a cylindrical housing. When hydraulic oil will be supplied to its cap end port, hydraulic pressure force will be applied over the piston or plunger and hence piston will be extended and this stroke of cylinder will be termed as forward stroke.
- For return stroke or during retraction of cylinder, piston or plunger will be returned due to its own weight or by any mechanical media i.e. spring force. When piston will start its retraction i.e. return stroke due to its self weight or spring force, oil will flow back to reservoir during retraction of cylinder.



- Hence piston will be operated hydraulically only in one direction i.e. during extension or forward direction. Retraction of cylinder will not be operated by hydraulic force but also it will be operated by mechanical force such as spring force or piston may also returns due to its self weight on the basis of design of cylinder.
- Single acting cylinders are classified in two types on the basis of mechanism of retraction of cylinder.
 1. Single acting cylinder- Gravity return

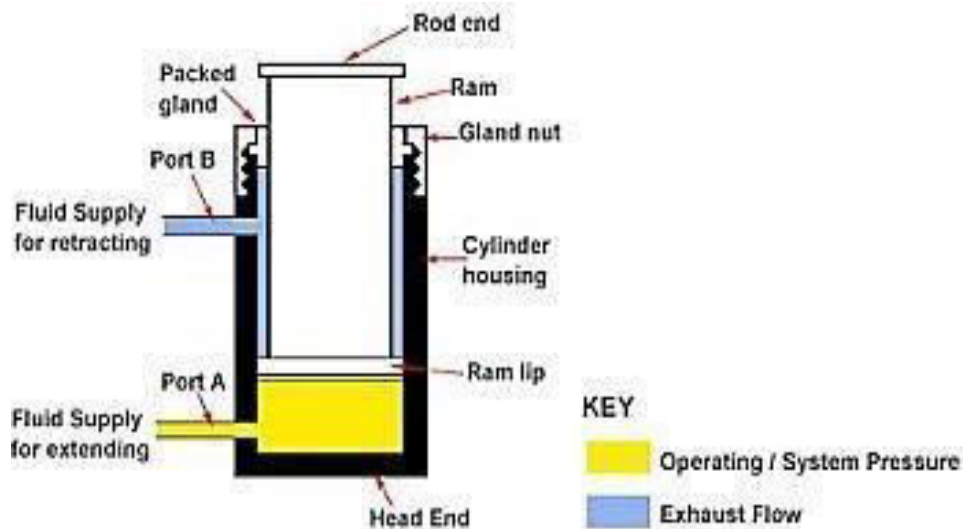


2. Single acting cylinder- Spring return

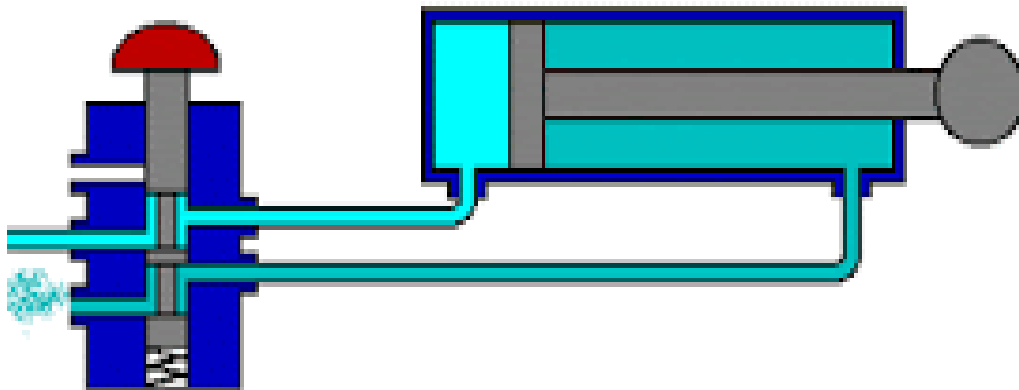


5.7.2 OPERATION OF DOUBLE ACTING CYLINDER

- Double acting hydraulic cylinder is also one type of hydraulic cylinder which is used for pulling, lifting, moving and holding the load. Double acting hydraulic cylinder, as shown in figure, will have two ports i.e. cap end port and rod end port.
- Double acting hydraulic cylinder, as name indicates, will be operated hydraulically in both direction i.e. forward direction and return direction.
- Double acting hydraulic cylinder will have one piston within a cylindrical housing. When hydraulic oil will be supplied to its cap end port, hydraulic pressure force will be applied over the piston or plunger and hence piston will be extended and this stroke of cylinder will be termed as forward stroke.
- During extension of the cylinder piston or plunger, hydraulic oil at rod end side will be pushed out and will be directed towards reservoir.



- For return stroke or retraction of cylinder, hydraulic fluid direction will be reversed with the help of direction control valve.
- During return stroke, hydraulic oil will be supplied to its rod end port and therefore hydraulic pressure force will be applied over the piston or plunger from rod end side and hence piston will be retracted and this stroke of cylinder will be termed as return stroke.
- During retraction of the cylinder piston or plunger, hydraulic oil at cap end side will be pushed out and will be directed towards reservoir.



Working of double acting hydraulic cylinder

- Hence double acting hydraulic cylinders will be operated hydraulically in both directions i.e. during extension or forward direction and also during retraction or return stroke. Direction of hydraulic oil will be changed with the help of double acting directional control valve or reversible pump could also be used for changing the direction of flow of fluid.

5.7.3 OPERATION OF DOUBLE ACTING CYLINDER WITH METERING IN AND METERING OUT CONTROL

METER-IN CIRCUIT

With this circuit, a flow control valve is installed in a pressure line that leads to a work cylinder. All flow entering a work cylinder is first metered through a flow control valve. Since this metering action involves reducing flow from a pump to a work cylinder, a pump must deliver more fluid than is required to actuate a cylinder at desired speed. Excess fluid returns to a tank through a relief valve. To conserve power and avoid undue stress on a pump, a relief valve's setting should be only slightly higher than a working pressure's, which a cylinder requires.

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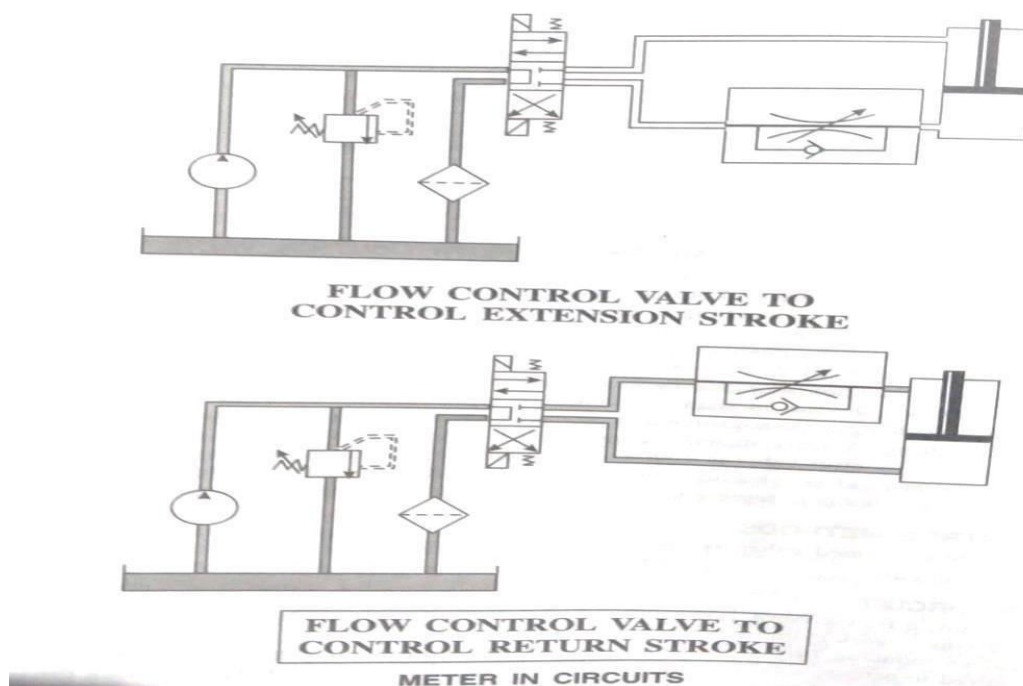
Application

A meter in circuit is ideal in applications where a load always offers a positive resistance to flow during a controlled stroke. Examples would be feeding grinder tables, welding machines, milling machines, and rotary hydraulic motor drives.

A flow control and check valve used in this type of circuit would allow reverse free flow for the return stroke of a cylinder, but it would not provide control of return stroke speed.

Drawback

The meter in circuit is circuit is advantageous and accurate only for positive loads. For loads that are overrunning the actuator does not control the speed of extension. This overrunning load creates cavity and vacuum.



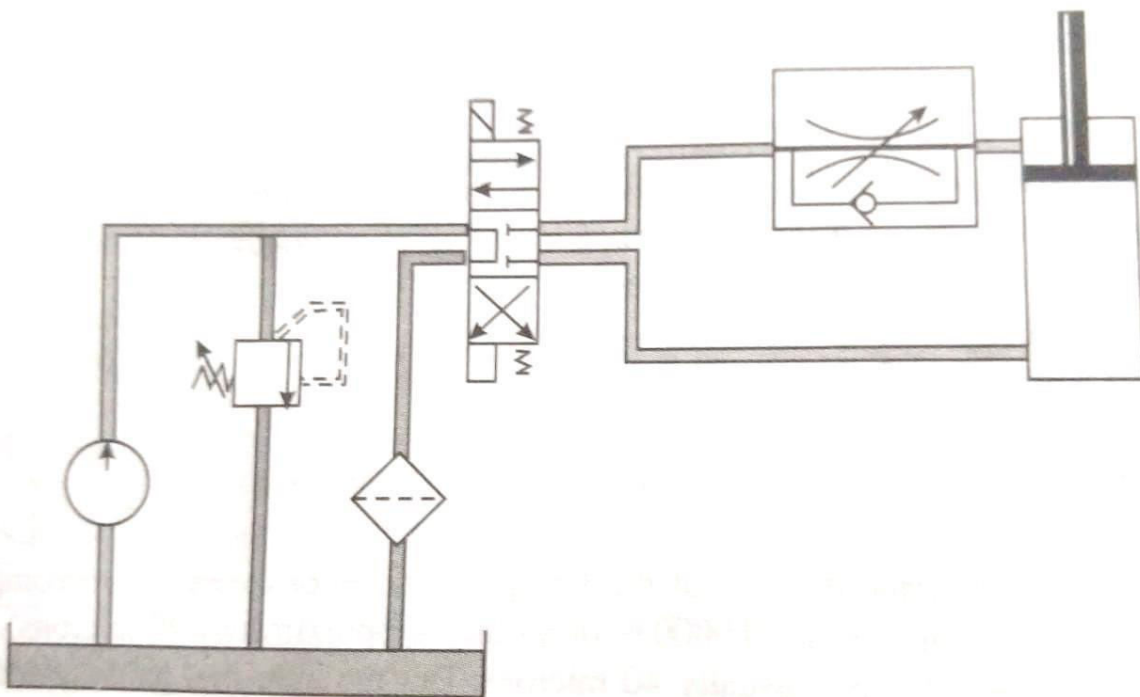
METER-OUT CIRCUIT

With meter-out circuit, a flow control valve is installed on the return side of a cylinder so that it controls a cylinder's actuation by metering its discharge flow. A relief valve is set slightly above the operating pressure that is required by the type of work.

Application

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This type of circuit is ideal for overhauling load applications in which a workload tends to pull an operating piston faster than a pump's delivery would warrant. Examples would be for drilling, reaming, boring, threading, tapping, cutting off and cold sawing machines. A flow control and check valve used in this circuit would allow reverse free flow, but it would not provide a control of return stroke speed.



The above circuit meters the oil coming from the Rod Side

METER-OUT CIRCUIT

Drawback

These types of circuits though they protect cylinder from overrunning, there is pressure intensification if the flow control valve is on the rod side of the cylinder and this damages the rod seals.

Note

Have a close look at the positioning of the control valve and check valve in the meter-in and meter-out circuits. Only change would be in the way the check valves are connected.

Both meter-in and meter-out circuits are effective but not efficient as the excess controlled flow passes through the relief valve back to the tank.

5.8 COMPARISON OF HYDRAULIC AND PNEUMATIC SYSTEM

ISSUES	HYDRAULIC SYSTEM	PNEUMATIC SYSTEM
power	Hydraulic tools are more powerful, because they use pressurized liquid.	Can not deliver the same pressure especially when the torque is required because it only uses pressurized air.
maintenance	Very little maintenance is required, as internal parts are always bathed in oil	More maintenance is required including draining moisture from air tanks, and constantly keeping tools oiled.
noise	Hydraulic tools are quiet.	Pneumatic tools are accompanied by loud compressor.
temperature	It will operate in sub-zero temperatures. They will not freeze up.	Due to moisture in the air, pneumatic tools can freeze up.
cost	About twice the cost of pneumatic tools.	Pneumatic systems is cheaper and easier to construct.

Short questions

1. What is the function of pump?

Ans-pump is a hydraulic device which convert kinetic of fluid into pressure energy.

2. What the function of hydraulic accumulator?

Ans- the function of hydraulic accumulator is to store energy in case of excess energy supply and release this energy when required

Long questions

Explain about following devices-

Hydraulic accumulators
Pressure control valves
Pressure relief valves
Pressure regulation valves
Direction control valves
3/2DCV,5/2 DCV,5/3DCV
Flow control valves
Throttle valves
Fluid power pumps
External and internal gear pumps
Vane pump
Actuators
Hydraulic circuits
Direct control of single acting cylinder
Operation of double acting cylinder
Operation of double acting cylinder with metering in and metering out control
Comparison of hydraulic and pneumatic system
ISO Symbols for hydraulic components.

