Applied Hydraulics and Pneumatics

UNIT-I-Fluid Power system and Fundamentals

By,

Dr.S.SURESH,
Assistant Professor,
Department of Mechanical Engineering

Objectives:

- knowledge on the applications of **Fluid Power** in **Power transmission system**. .
- To study the fundamental principles, design and operation of **hydraulic and pneumatic machines**, components and systems and their application in recent automation revolution.
- Understanding of the **fluids and components** utilized in modern industrial fluid power system.
- To design, construction and operation of **fluid power circuits**.

FLUID POWER:

- The common methods of power transmission are

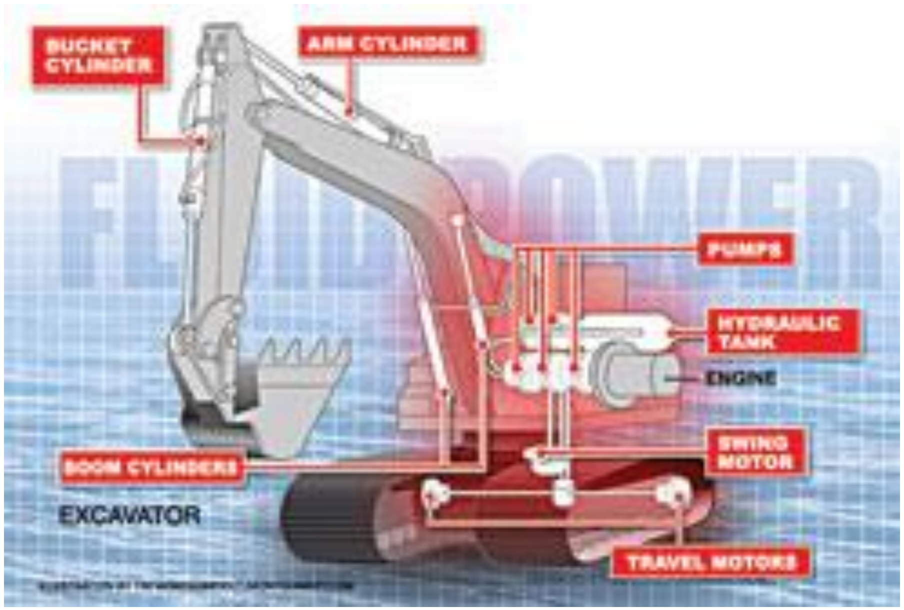
  Electrical,

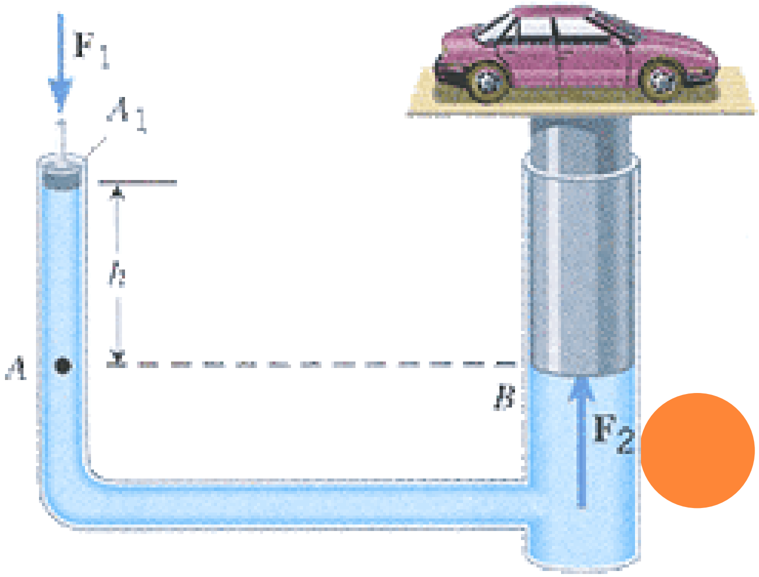
  Mechanical, and

  Fluid power.

FLUID POWER:

- It may be defined as the technology that deals with the generation, control and transmission of power using pressurized fluids.
- Use a fluid (liquid or gas) to transmit power from one location to another.
- Hydraulics - liquid (usually oil),
  Pneumatics - gas (usually compressed air).





ADVANTAGES OF FLUID POWER

- Easy and Accuracy to Control With the use of simple levels
- Multiplication of small forces to achieve greater forces for performing work
- It easily provides infinite and step less variable speed control which is difficult to obtain from other drives
- Accuracy in controlling small or large forces with instant reversal is possible with hydraulic systems
- As the medium of power transmission is fluid, it is not subjected to any breakage of parts as in mechanical transmission

Cont…

- The parts of hydraulic system are lubricated with the hydraulic liquid itself.
- Overloads can easily controlled by using relief valves
- Because of the simplicity and compactness the cost is relatively low for the power transmitted.
- No need of lubrication.

DISADVANTAGES:

1. Leakage of oil or compressed air

2. Busting of oil lines, air tanks

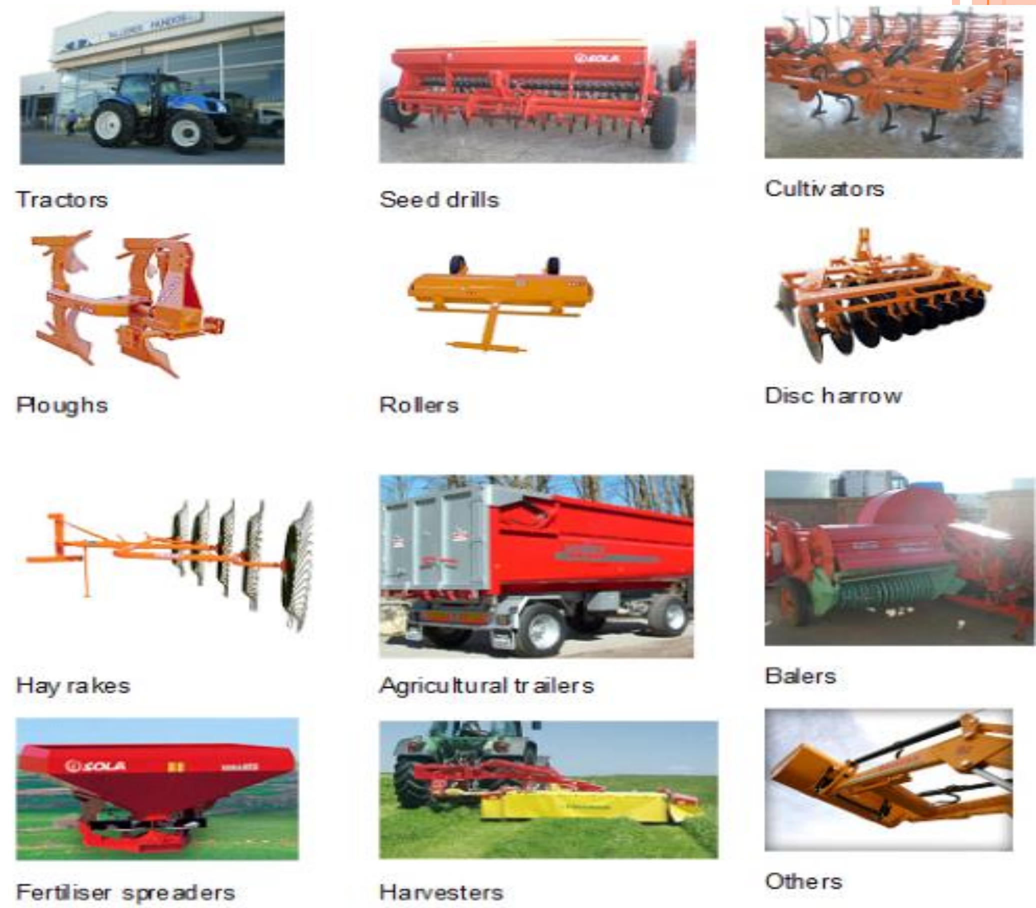
3. More noise in operation

APPLICATIONS OF FLUID POWER:

1. **Agriculture:**

   Tractors and

   farm equipments like ploughs, mowers, chemical sprayers, fertilizer spreaders, haybalers



2. **Automation:**

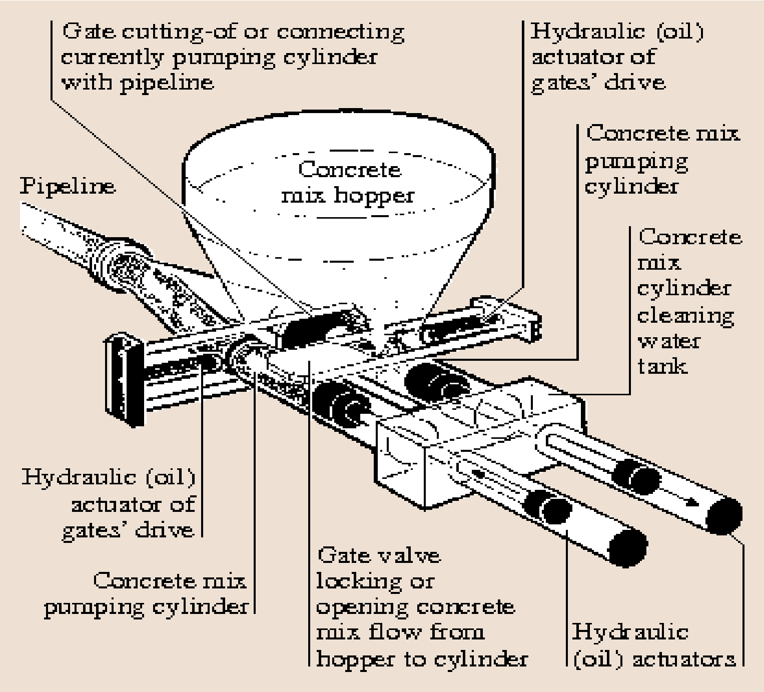
   Automated transfer machines

3. Aviation:

Fluid power equipments like landing wheels on aeroplane and helicopter, aircraft trolleys, aircraft engine testbeds.

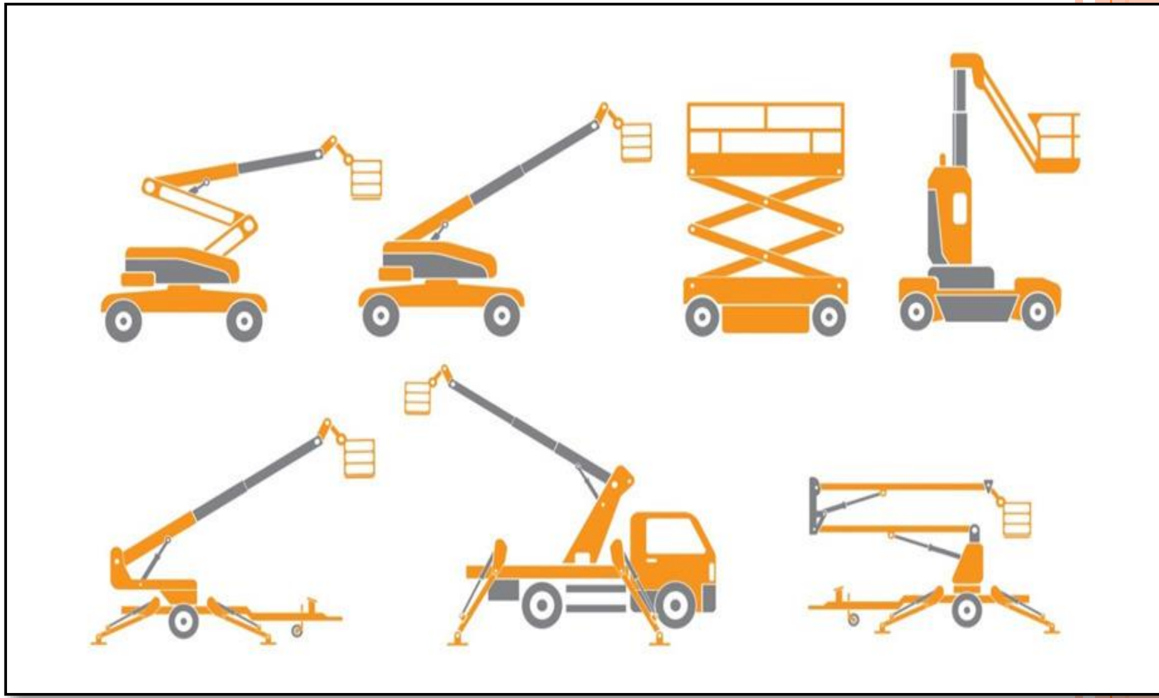
4. Building Industry:

For metering and mixing of concrete ingredients from hopper.



5. **Construction Equipment:**

Earthmoving equipments like excavators, bucket loaders, dozers, crawlers, post hole diggers and road graders.

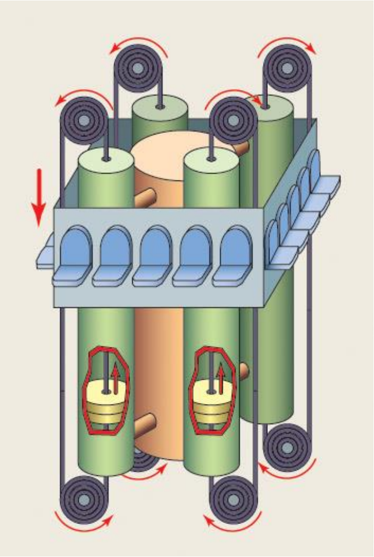


6. **Defense :**

Missile-launch systems and Navigation controls

7. **Entertainment:**

Amusement park entertainment rides like roller coasters



8. **Fabrication Industry:**

Hand tools like pneumatic drills, grinders, bores, riveting machines, nut runners

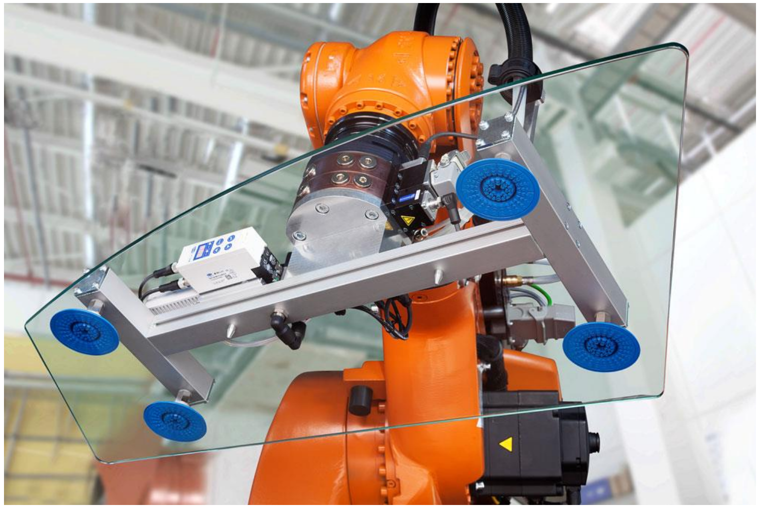
9. **Food and Beverage:**

All types of food processing equipment, wrapping, bottling

10. **Foundry:**

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

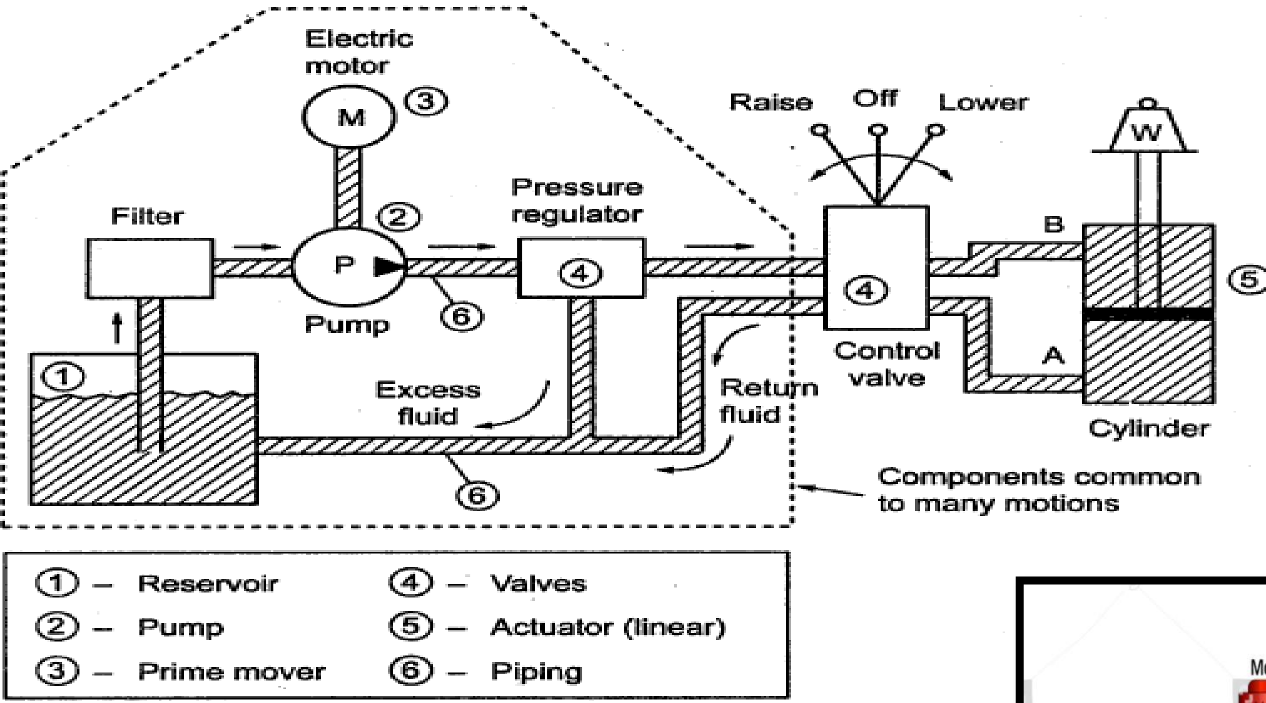
11. **Glass Industry:**
Vacuum suction cups for handling



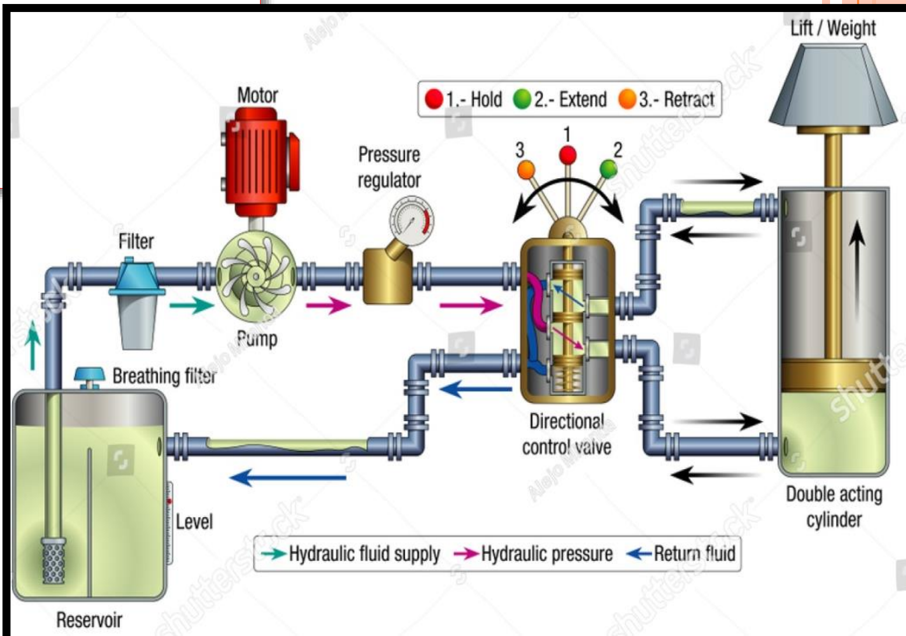
12. **Material Handling:**
Jacks, Hoists, Cranes, Forklift, Conveyor system

FLUID POWER SYSTEMS

1. HYDRAULIC POWER SYSTEMS



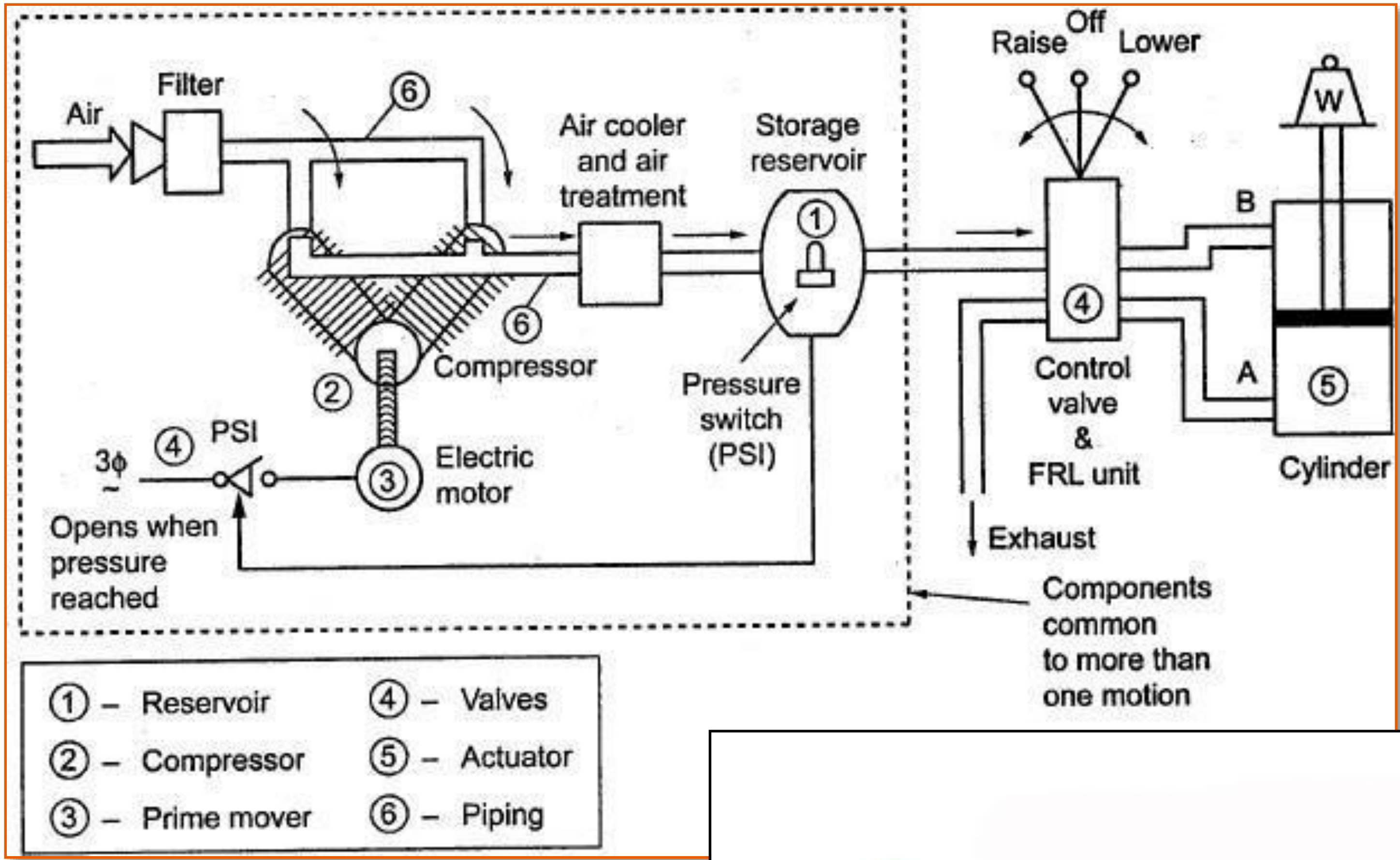
General arrangement of a hydraulic system

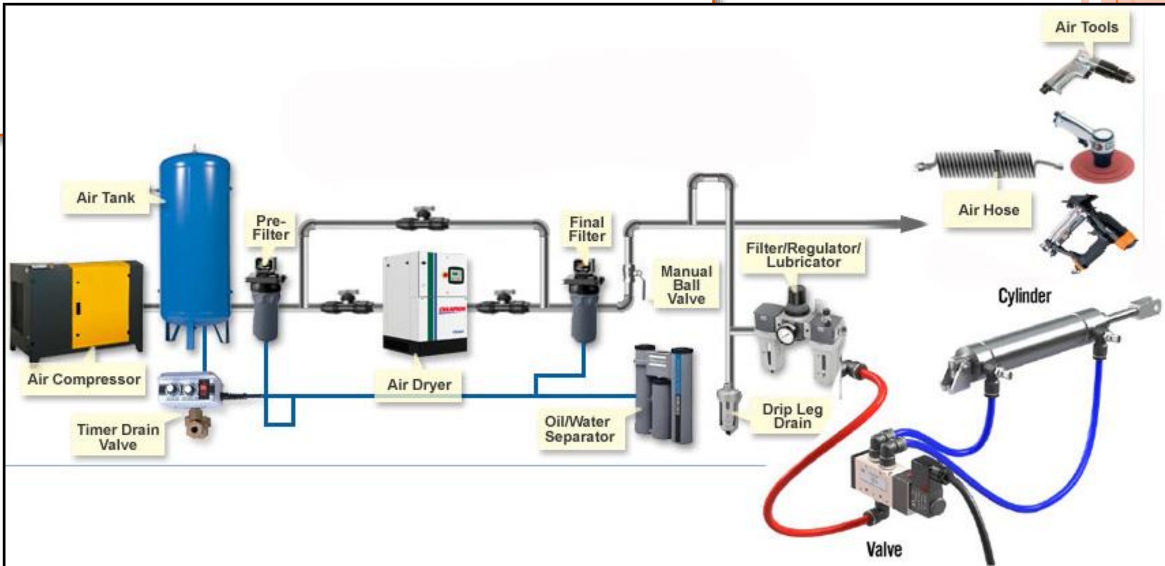


Basic Components of Hydraulic System

1. Reservoir (Tank)
2. Pump
3. Prime mover
4. Valves
5. Actuators
6. Fluid-transfer piping

2. Pneumatic Power Systems





Hydraulics Vs Pneumatics Vs Electro-Mechanical power system System

Hydraulic System	Pneumatic System	Electro-Mechanical
Pressurized Liquid is used	Compressed Air is used	Energy is transmitted through mechanical components
Energy stored in Accumulator	Energy stored in Tank	Energy stored in Batteries
Hydraulic Valves are used	Pneumatic Valves are used	Variable Frequency drives
Transmission through Hydraulic cylinders, Actuators	Transmission through Pneumatic cylinders, Actuators	Transmission through Mechanical components like Gears, Cams

CONT…

Hydraulic System	Pneumatic System	Electro-Mechanical
More Precision	Less Precision	More Precision
Large force can be generated	Limited force can be achieved	Large force can be realized but poor in efficiency
Medium Cost	High cost	Low Cost
Dangerous and fire hazardous because of leakage	Noisy	Easy to work

Fluids and Their Properties

Functions of Fluid Power in Fluid Power system

1. Transfer fluid power efficiently
2. Lubricate the moving parts
3. Absorb, Carry and Transfer heat generated within the system
4. Be compatible with hydraulic components
5. Remain stable against physical and chemical changes

Properties of hydraulic fluids

Density

- The density of a fluid is its mass per unit volume.
- Liquids are essentially incompressible
- Density is highly variable in gases nearly proportional to the pressure.

Viscosity

Viscosity is a measure of a fluid's resistance to flow. It determines the fluid strain rate that is generated by a given applied shear stress.

CONT...

- **Viscosity Index:**

  This value shows **how temperature affects the viscosity** of oil.

  The viscosity of the oil decreases with increase in temperature and vice versa.

  The rate of change of viscosity with temperature is indicated on an arbitrary scale called viscosity

- **Cohesion**
  - Intermolecular attraction between molecules of same liquid
- **Adhesion**
  - Attraction between molecules of liquid and molecules of solid boundary in contact with liquid.

- **Cavitation**

  Cloud of vapour bubble will form when liquid pressur drops below vapour pressure due to flow phenomenon.

- **Pour Point:**

  The lowest temperature at which the oil is able to flow easily.

- **Flash Point and Fire Point:**

  The minimum temperature at which the hydraulic fluid will catch fire and continue burning is called fire point.

- **Lubricity:**

  Wear results in increase clearance which leads to all sorts of operational difficulties including fall of efficiency.

REQUIRED QUALITIES OF GOOD HYDRAULIC OIL:

- Stable viscosity characteristics
- Good lubricity
- Compatibility with system materials
- Stable physical and chemical properties
- Good heat dissipation capability
- High bulk modulus and degree of incompressibility
- Good flammability
- Low volatility
- Good demulsibility
- Better fire resistance
- Non toxicity and good oxidation stability
- Better rust and corrosion prevent qualities
- Ready availability and inexpensive

Types of Hydraulic Fluids

1. Water:

The least expensive hydraulic fluid is water.

Water is treated with chemicals before being used in a fluid power system.

Advantages: Inexpensive, Readily available, Fire resistance

Disadvantage: No lubricity, Corrosive, Temperature limitations

2. Petroleum Oils:

These are the most common among the hydraulic fluids

The characteristic are controlled by the type of crude oil used.

Naphthenic oils have low viscosity index so it is unsuitable where the oil temperatures vary too widely.

Advantages: Excellent lubricity, Reasonable cost, Non-corrosive

3. Water Glycols:

These are solutions contains 35 to 55% water, glycol and water soluble thickener to improve viscosity. Additives added to improve anticorrosion, anti wear and lubricity properties.

Advantages: Better fire resistance, Less expensive, Compatible with most pipe compounds and seals

Disadvantage: Low viscosity, Poor corrosion resistance, not suitable for high loads.

4. Water Oil Emulsions:

Water-oil mixtures.

Types: oil- in-water emulsions or water-in-oil emulsions.

The oil-in-water emulsion has water as the continuous base and the oil is present in lesser amounts as the dispersed media.

In the water-in-oil emulsion, the oil is in continuous phase and water is the dispersed media.

Advantages: High viscosity index, Oxidation stability, Film strength

Disadvantage: Depletion of water due to evaporation decreases fire resistance, Demulsification may be problem with water-in-oil emulsions.

5. Phosphate Ester:

It results from the incorporation of phosphorus into organic molecules. They have high thermal stability. They serve as an excellent detergent and prevent building up of sludge.

Advantages: Excellent fire resistance, Good lubricity, Non corrosive

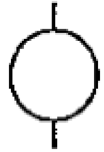
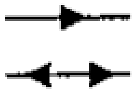
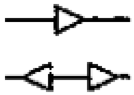
Disadvantage: Not compatible with many plastics and elastomers, Expensive

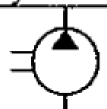
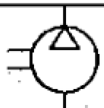
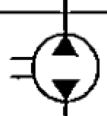
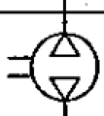
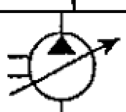
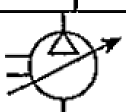
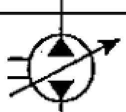
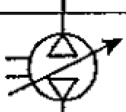
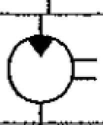
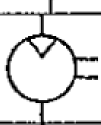
FLUID POWER SYMBOLS

- Due to the rapid development of fluid-power applications, **standard fluid power symbols and specifications** are developed to facilitate communication and to provide a universal means of representing fluid-power symbols.
- Illustrate flow paths, connections and component functions.
- Basic Symbol Classifications

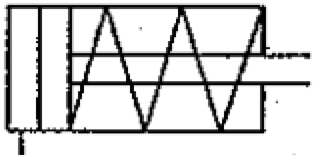
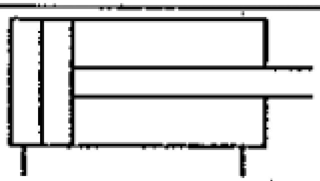
1. Pumps and motors;
2. Cylinders;
3. Directional control valves;
4. Pressure valves;
5. Flow control valves;
6. Non-return valves;
7. Operation/actuation methods;
8. Energy transmission;
9. Measuring devices;
10. Couplings, and
11. Combination of devices.

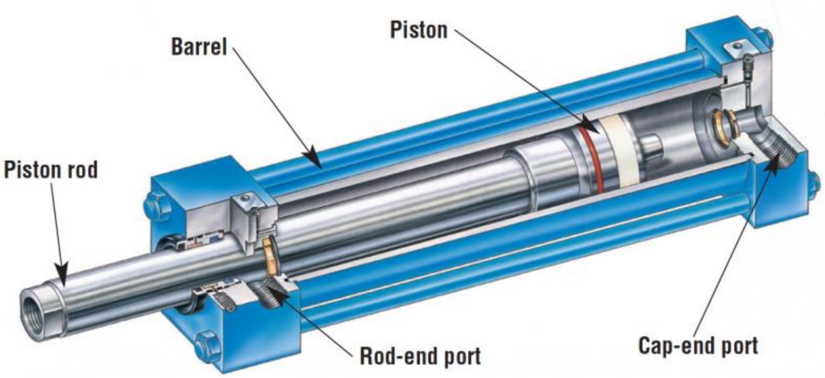
Pumps and Motors

Circle		Represents a pump, motor, or any rotary devices.
Filled triangle		Indicates the direction of flow for hydraulic fluid (system).
Unfilled triangle		Indicates the direction of flow for pneumatic fluid (system).
Line with an arrow		Indicates the variable displacement.

Description	Symbol	Diagram	
		Hydraulic	Pneumatic
Fixed displacement, unidirectional pump	S1		
Fixed displacement, bidirectional pump	S2		
Variable displacement, unidirectional pump	S3		
Variable displacement, bidirectional pump	S4		
Fixed displacement, unidirectional motor	S5		

Cylinders

Description	Symbol	Diagram
Single acting cylinder, returned by external force	S10	
Single acting cylinder, with spring return	S11	
Double acting cylinder with single piston rod	S13	

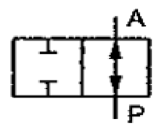
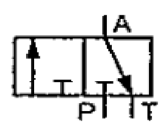
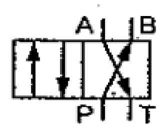
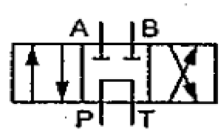


Directional control valve

To determine the path of the fluid through which it should travel within a given circuit.

Number of squares	–	Indicates the number of switching positions possible.
Arrow within square	–	Indicate the flow direction.
Lines	–	Indicate how the ports are inter-connected in the various switching positions.

Example : 4/3 valve has 4 ports and 3 switching positions.

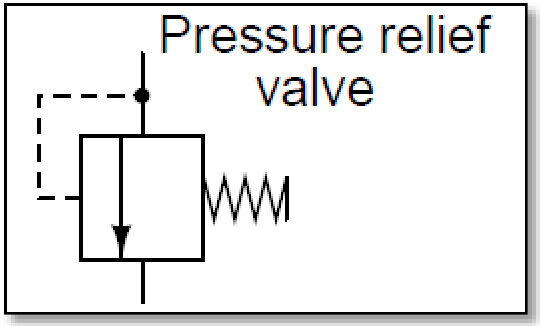
Description	Symbol	Diagram
2/2 – way valve	S20	
3/2 – way valve	S21	
4/2 – way valve	S22	
4/3 – way valve	S23	

Pressure Relief Valve

✓ Used to product the fluid power system against over pressure.

Pressure valves are indicated using squares.

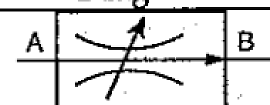
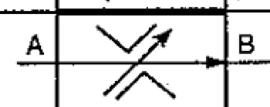
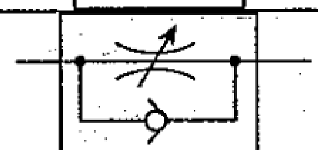
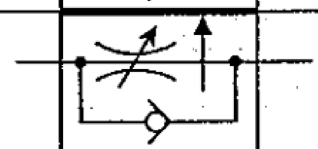
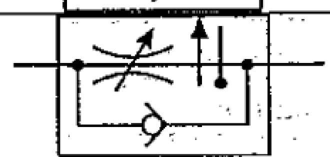
Arrow – Indicates flow direction



Flow Control Valve

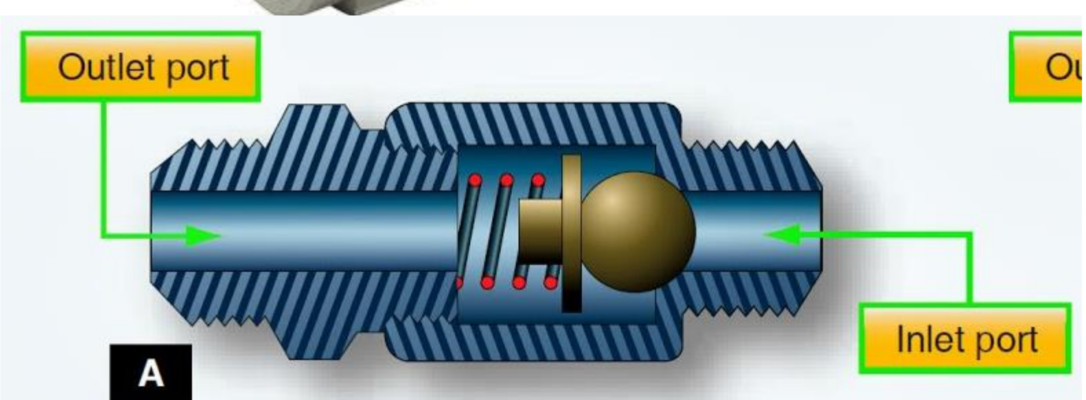
- ✓ The purpose of a flow control valve is **to regulate the flow rate in a specific portion of a hydraulic circuit**.
- ✓ In hydraulic systems, they're used to control the flow rate to motors and cylinders, thereby regulating the speed of those components.

Orifice	–	Flow control valves unaffected by viscosity.
Throttle	–	Constitute resistance in a hydraulic system.
Rectangle	–	Indicates flow control valve.
Diagonal arrow	–	Indicates that the valve is adjustable.

Description	Symbol	Diagram
Adjustable flow control valve with throttle	S27	
Adjustable flow control valve with orifice	S28	
Adjustable with bypass	S29	
Adjustable and pressure compensated with bypass	S30	
Adjustable temperature and pressure compensated	S31	

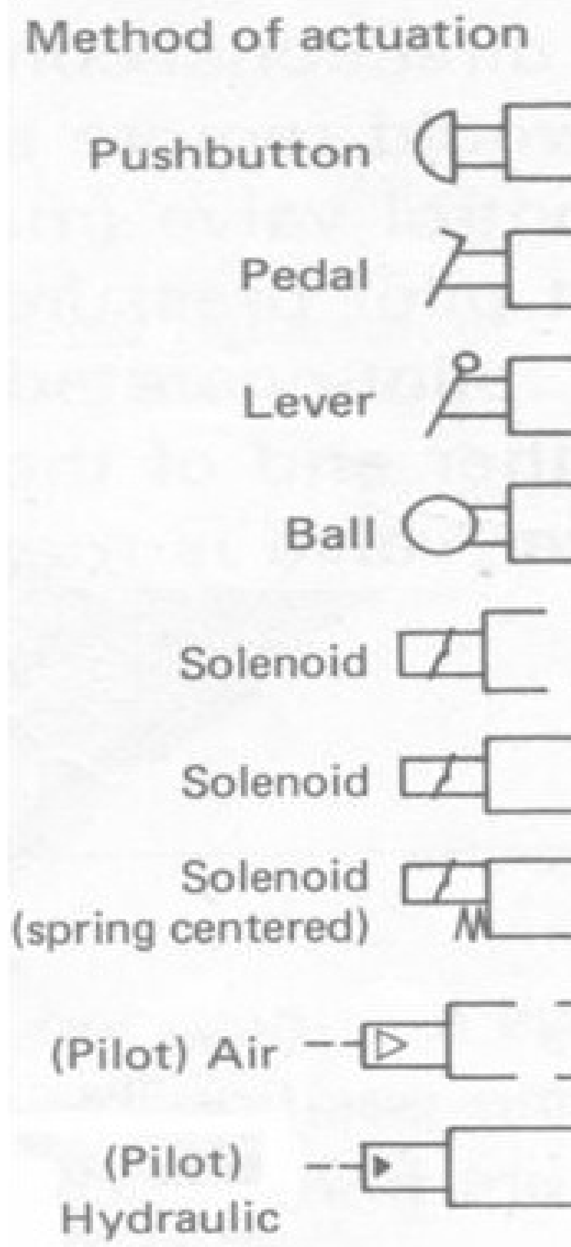
Non-return valve

Description	Symbol	Diagram
Spring loaded non-return valve	S32	B A
Unloaded non-return valve	S33	B A
Pilot controlled non-return valve	S34	A B
Shut-off valve	S35	B A X

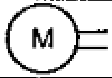
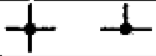
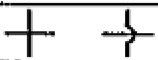
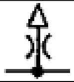
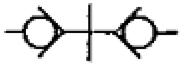
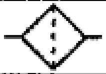
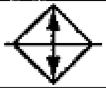
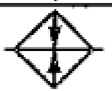


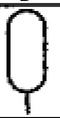
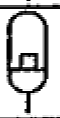
Switching position of Directional Control Valve

- Manual Actuation
  - Push button
  - Lever
  - Pedal
- Mechanical Actuation
  - Spring
  - Ball and Cam
- Fluid (Pilot)
  - Air (pneumatic)
  - Oil (hydraulic)
- Electromagnetic (solenoid)

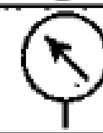
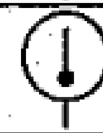
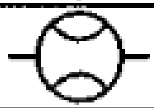
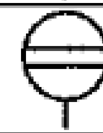


• Energy Transmission

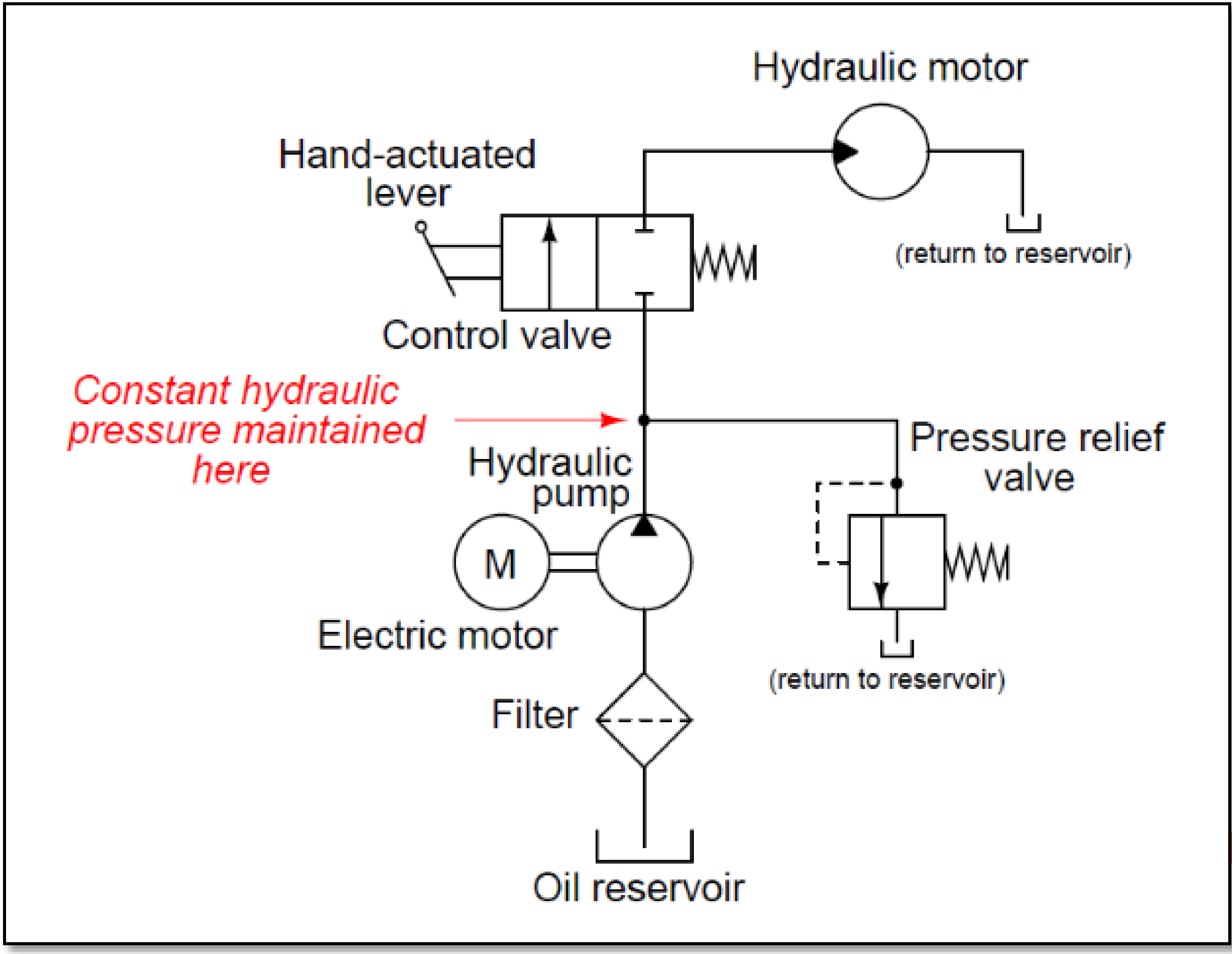
Description	Diagram
Hydraulic pressure source	
Electric motor	
Non-electric drive unit	
Pressure, power, return line	
Control (pilot) line	
Drain line	
Plugged port	
Flexibtle line	
Line connection	
Line crossing	
Exhaust, continuous	
Quick-acting coupling connected with mechanically opening non-return valves	
Vented reservoir	
Pressurized reservoir	
Filter	
Cooler	
Heater	

Description	Diagram
Accumulator	
Spring loaded accumulator	
Gas charged accumulator	
Weighted accumulator	

Measuring Devices

Description	Symbol	Diagram
Pressure gauge	S66	
Thermometer	S67	
Flowmeter	S68	
Filling level indicator	S69	

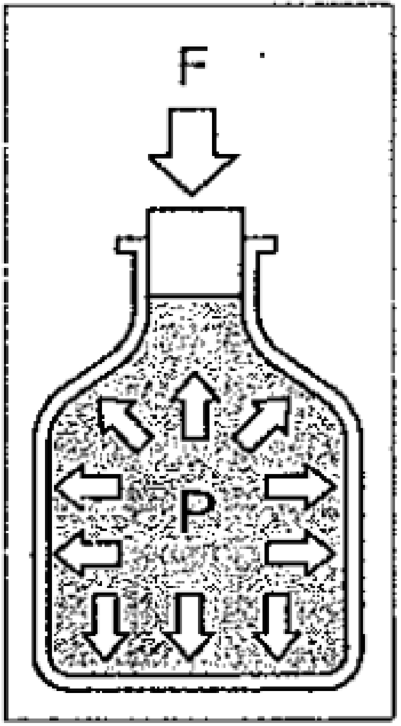
Sample Hydraulic System



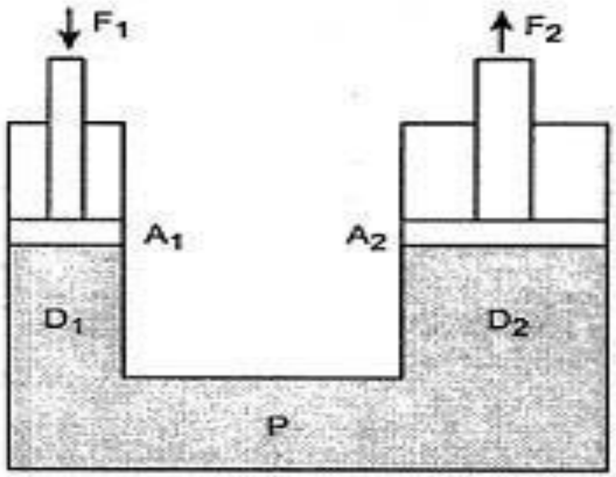
Basics of Hydraulics

PASCALS LAW:

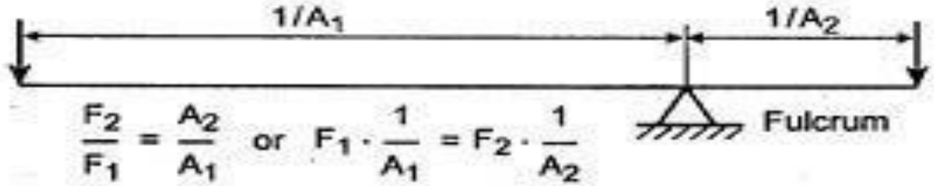
This law states that the pressure generated at any point in a confined fluid acts equally in all directions.



Consider two oil containers both in cylindrical form and connected together contain some oil, as shown Both the cylinders have a piston having different diameters says D_1 and D_2 respectively, where D_1 is smaller than D_2.



Principle of Bramah's press



A hydraulic lever

If a force F_1 is applied to the small-diameter piston, then this will produce an oil pressure P_1 at the bottom of the piston 1. Now this pressure is transmitted through the oil to the large-diameter piston 2. Because the piston 2 has a larger area (A_2), the pressure at the bottom of the piston 2 will be P_2. Now this pressure P_2 will push up the piston 2 to create an output force F_2.

We know that according to Pascal's law, $P_1 = P_2$

or
$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

or
$$\boxed{\frac{F_2}{F_1} = \frac{A_2}{A_1}}$$

where A_1 = Area of the smaller piston $= \frac{\pi}{4} D_1^2$, and

A_2 = Area of the larger piston $= \frac{\pi}{4} D_2^2$.

FLUID FLOW:

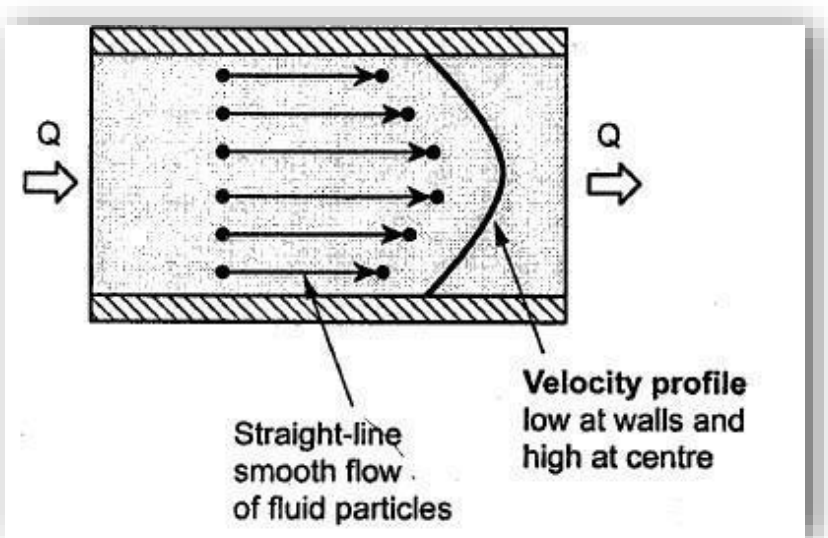
- **Laminar Flow:**

It is one in which paths taken by the individual partials **do not cross one another** and moves along well defined paths.

Characterized by the fluid flowing in **smooth layers** of lamina.

This type of flow is also known as **streamline or viscous flow**.

Examples: Flow of oil in measuring instruments



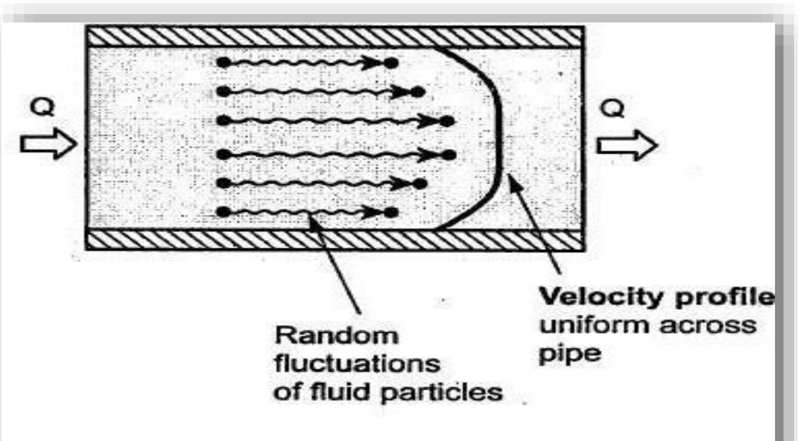
Turbulent Flow:

It is that flow in which fluid particles move in a zigzag way.

Small fluctuations in the magnitude and direction of the velocity of the fluid particles.

It causes more resistance to flow, Greater energy loss and increase fluid temperature

Examples: High velocity flow in a pipe of large size



Turbulent flow

REYNOLDS NUMBER:

- Determines non-dimensional quantity
- Equation to determine whether the flow is laminar or turbulent.

$$Re = \frac{\rho V D}{\mu}$$

ρ = Density of fluid (kg/m^3)
V = Velocity of Flow (m/sec)
D = Inside diameter of pipe (m)
υ = Kinematic viscosity of fluid (m^2/sec)
μ = absolute viscosity of fluid (Ns/m^2)

1. *If Reynolds number (Re) < 2000, then the flow in pipes is **laminar**.*
2. *If Reynolds number (Re) > 4000, then the flow in pipes is **turbulent**.*
3. If Reynolds number is between 2000 and 4000, then the flow in pipes is unpredictable.

Darcy's Equation

- The major energy losses (i.e., losses due to friction in the pipe) can be calculated by using Darcy's Equation.
- Head loss due to friction in pipes carrying fluids are derived as

$$H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

where H_L = Loss of head due to friction in pipe in m,

f = Friction factor,

L = Length of pipe in m,

D = Inside diameter of the pipe in m,

V = Average velocity of liquid in m/s, and

g = Acceleration due to gravity in m/s^2.

LOSSES IN VALVES AND FITTINGS:

The loss of head in the various valves and fittings is

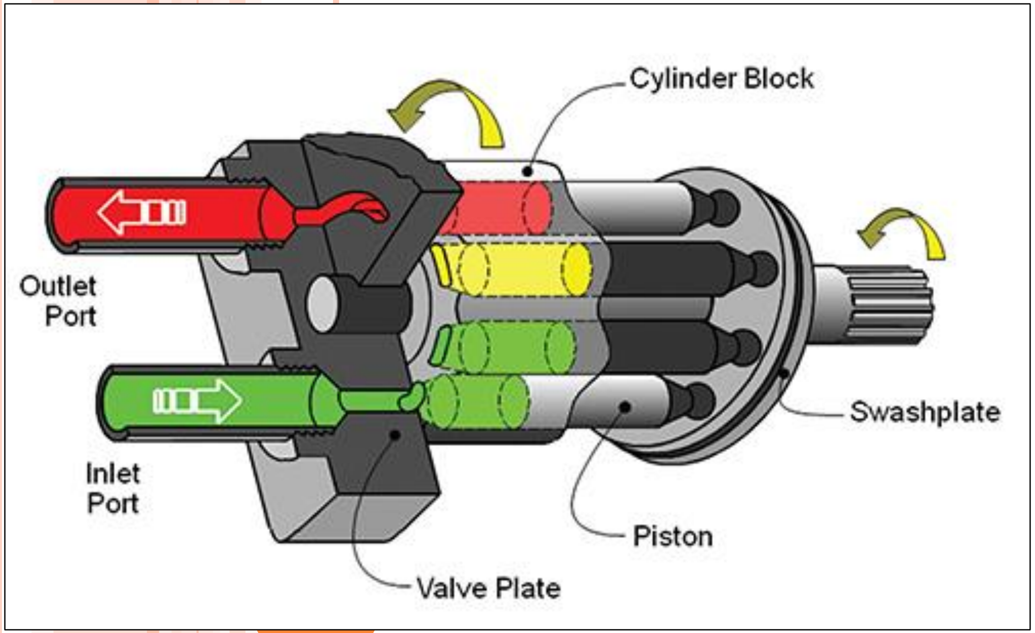
$$H_L = K\left(\frac{V^2}{2g}\right)$$

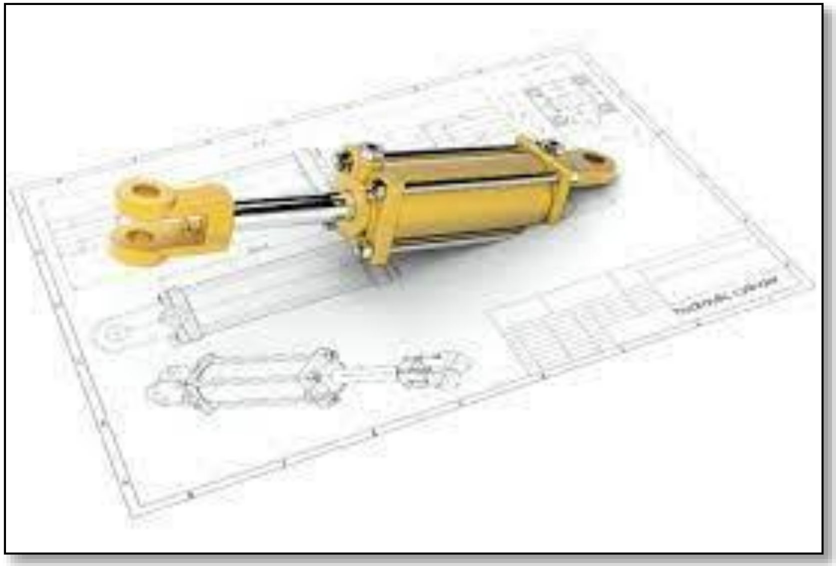
where K = Constant of proportionality called 'the *K-factor*'.

Valve or Fitting		K-Factor
Globe valve :	Wide open	10.0
	½ open	12.5
Gate valve :	Wide open	0.19
	¾ open	0.90
	½ open	4.5
	¼ open	24.0
Return bend		2.2
Standard tee		1.8
Standard elbow		0.9
45° Elbow		0.42
90° Elbow		0.75
Ball check valve		4.0

Applied Hydraulics and Pneumatics

UNIT-II-Hydraulic System and Components





By,

Dr.S.SURESH,

Assistant Professor,

Department of Mechanical Engineering

What is the pump?

- Pumps are machines which supply energy to liquid in order to move it from place to another.
- Hydraulic pumps convert mechanical energy from a prime mover (engine or electric motor) into hydraulic (pressure) energy.

The pressure energy is used then to operate an actuator.

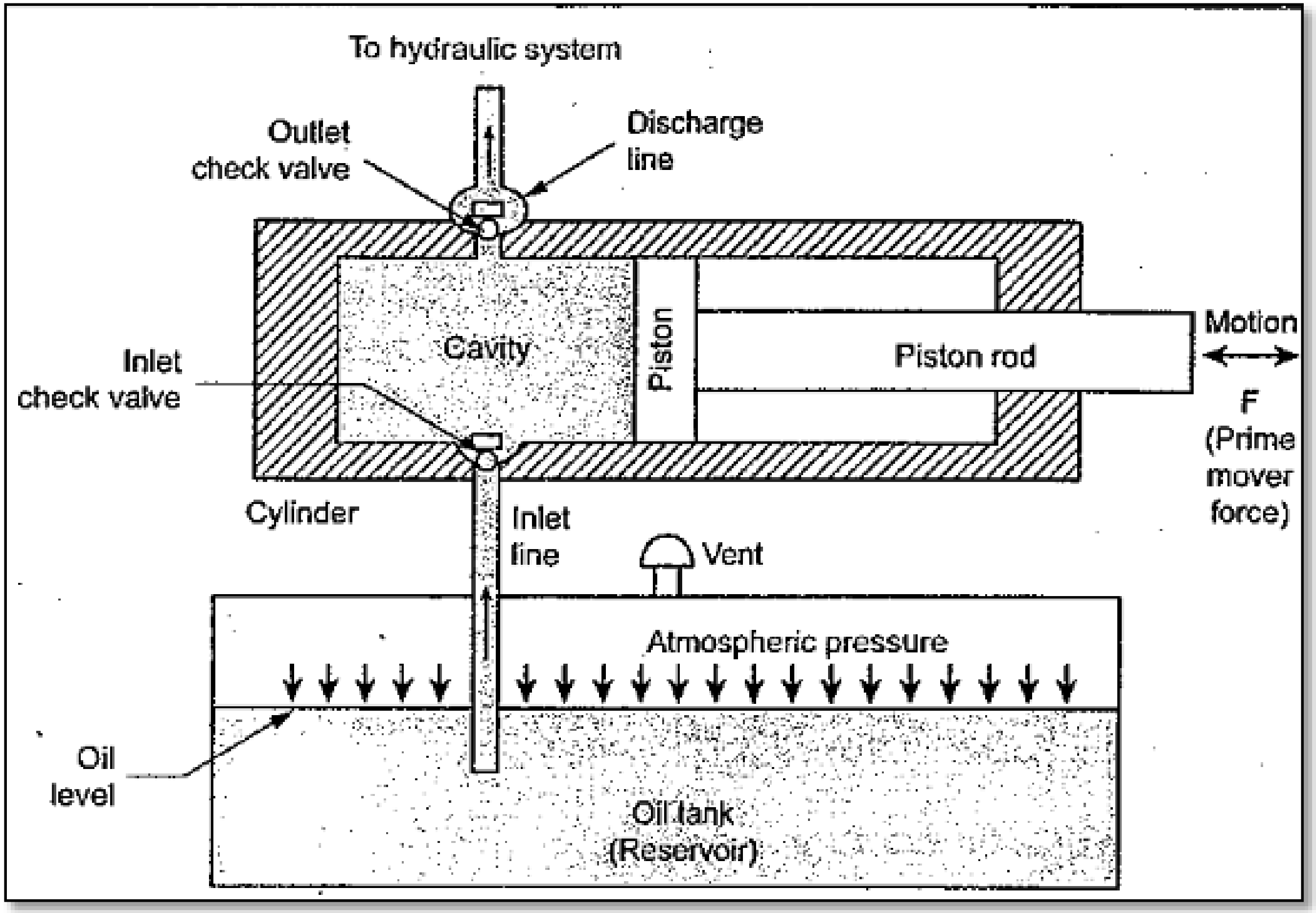
- Pumps push on a hydraulic fluid and create flow.
- Pumps enable liquid to :-

  1- flow from a region or a low pressure to one of high pressure.

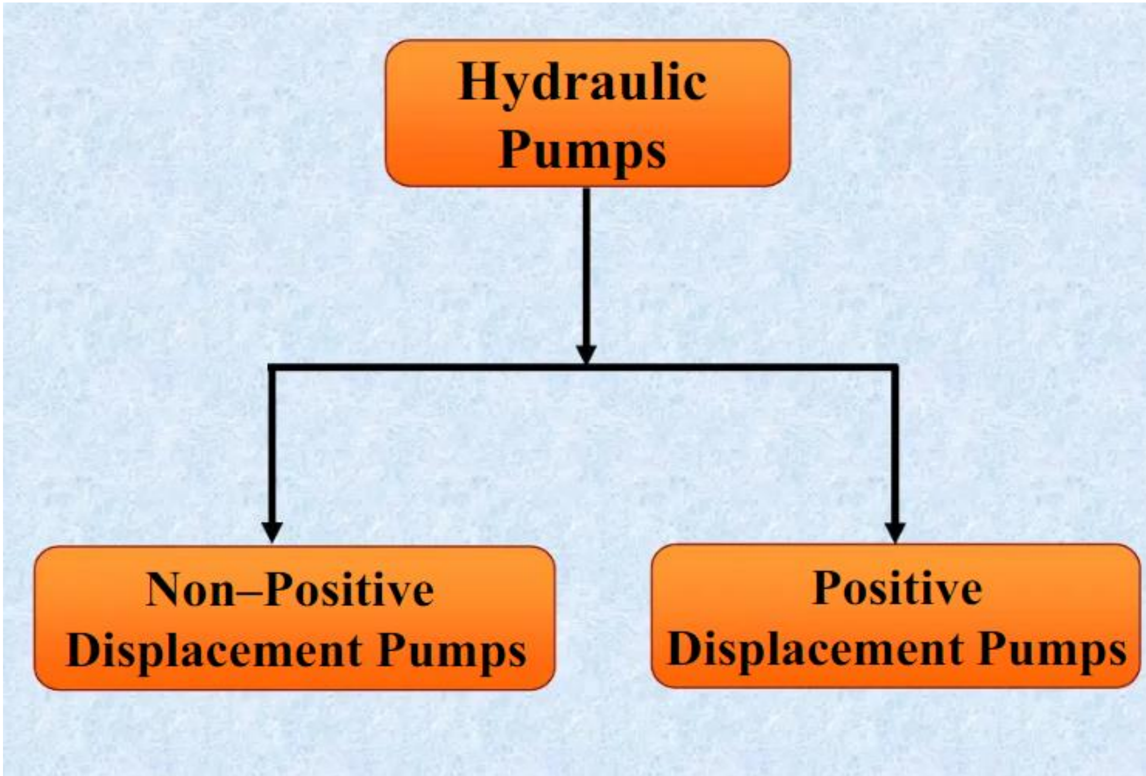
  2- flow from a low level to a higher level.

  3- flow at a faster rate.

PUMPING THEORY



Pump Classification



The flow rate decreases with head	The flow rate does not change with head
The flow rate decreases with the viscosity	The flow rate is not much affected by the viscosity of fluid
Efficiency increases with head at first and then decreases	Efficiency is almost constant with head

Types of Positive Displacement Pump

Rotary Type

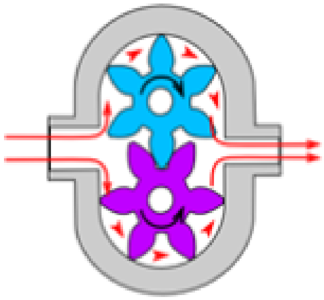
- Gear pump
- Screw pump
- Rotary vane

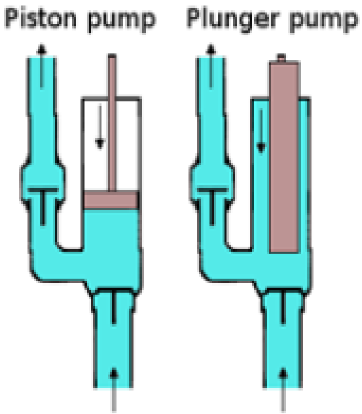
Reciprocating Type

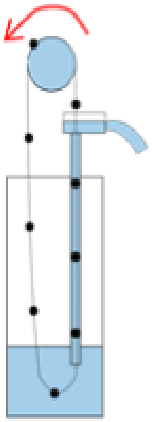
- Plunger
- Piston
- Diaphragm
- Circumferential piston

Linear Type

- Rope pumps
- Chain pumps







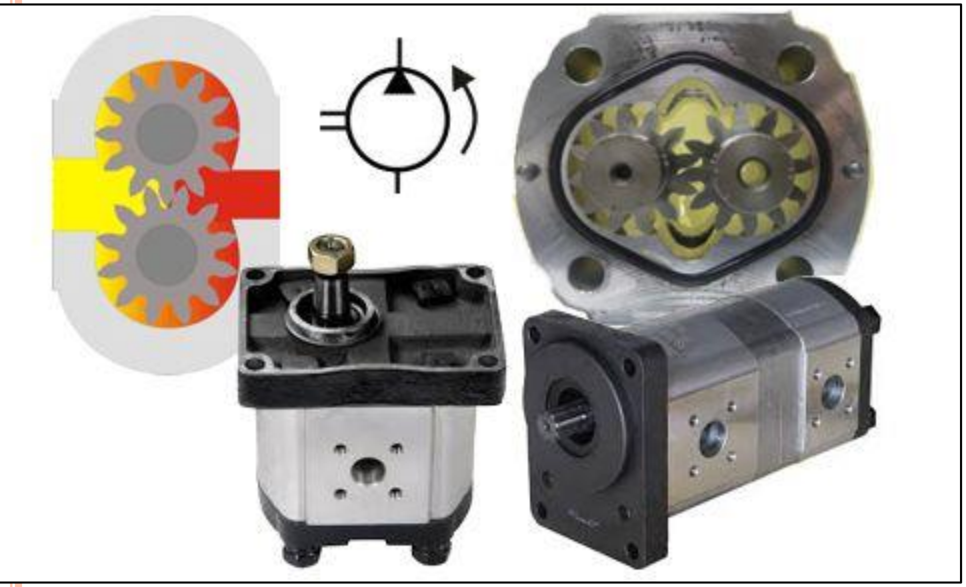
1. Gear Pump

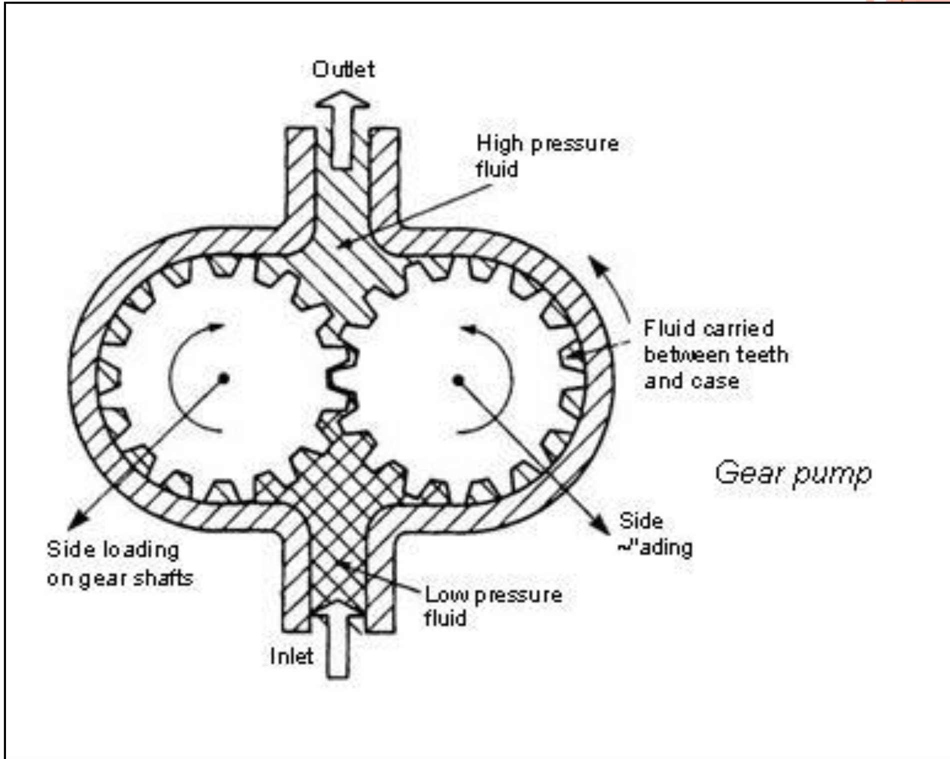
External Gear Pump:

Introduction

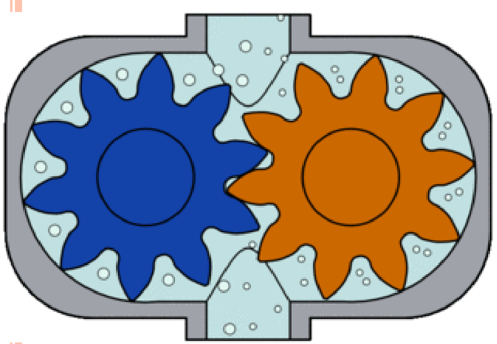
- Simplest and most robust positive displacement pump, having just two moving parts.
- Fixed displacement pump

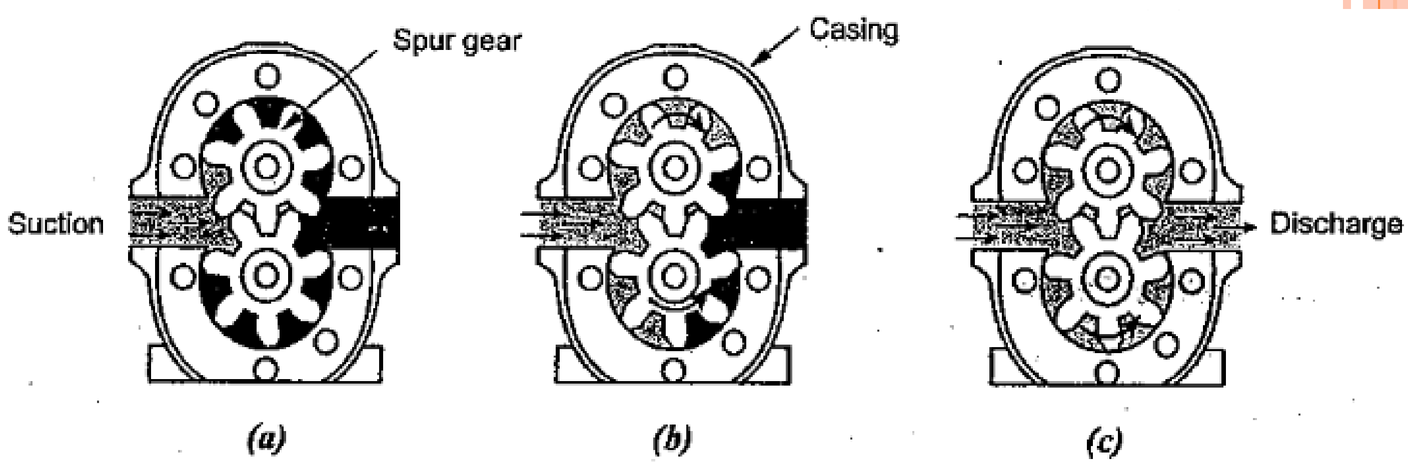
Construction





- Consists of just two close meshing gear wheels which rotate as shown.
- As the teeth come out of mesh at the centre, a partial vacuum is formed which draws fluid into the inlet chamber.
- Fluid is trapped between the outer teeth and the pump housing, causing a continual transfer of fluid from inlet chamber to outlet chamber where it is discharged to the system.





Operation of external gear pumps : (a) Vacuum draws fluid into pump. (b) Teeth carry fluid through pump. (c) Fluid is discharged under pressure

Volumetric Displacement and Theoretical Flow rate

The displacement of the gear pump is determined by volume of fluid between each pair of teeth, Number of teeth and speed of rotation.

The volumetric displacement, from the geometry of the gear teeth, is given by,

$$V_D = \frac{\pi}{4}(D_o^2 - D_i^2)L$$

Then the theoretical flow rate can be calculated as

$$Q_T = \frac{V_D \times N}{60}$$

Let D_i = Inside diameter of gear teeth in m,

D_o = Outside diameter of gear teeth in m,

L = Width of gear teeth in m,

N = Speed of pump in rpm,

V_D = Volumetric displacement of the pump in m^3/rev, and

Q_T = Theoretical pump flow rate in m^3/sec.

Advantages	Disadvantages
✓ These pumps are self-priming. ✓ They give constant delivery for a set rotor speed, uniform discharge with negligible pulsations, and do no require check valves. ✓ If necessary, these pumps can pump in either direction (by changing the direction of the gear rotation). ✓ They have small space requirements. ✓ They are light in weight. ✓ They can handle liquids containing vapours and gases. ✓ Volumetric efficiency is high.	✓ The liquid to be pumped must be comparatively clean. ✓ The pump cannot be operated against a closed discharge without damage. Hence relief valves are required. ✓ Variable-speed drives are required to provide changes in pumping rate. ✓ These pumps depend on the liquid pumped to lubricate the internal moving parts and can be damaged if run dry.

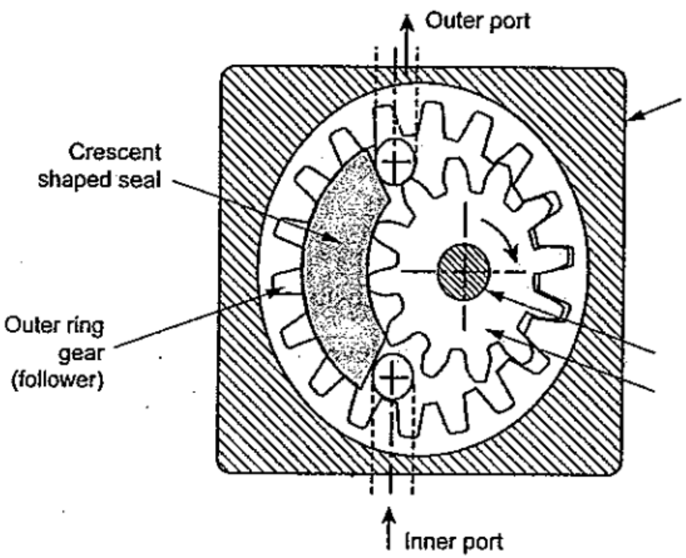
External Gear Pump Applications

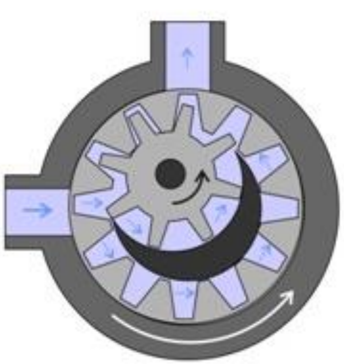
- Chemical blending and compounding
- Used in lube and fuel oils
- Polymers and solving agents
- Caustic and acidic fluids
- Hydraulic, farming and engineering applications
- Polymer metering and chemical extracts

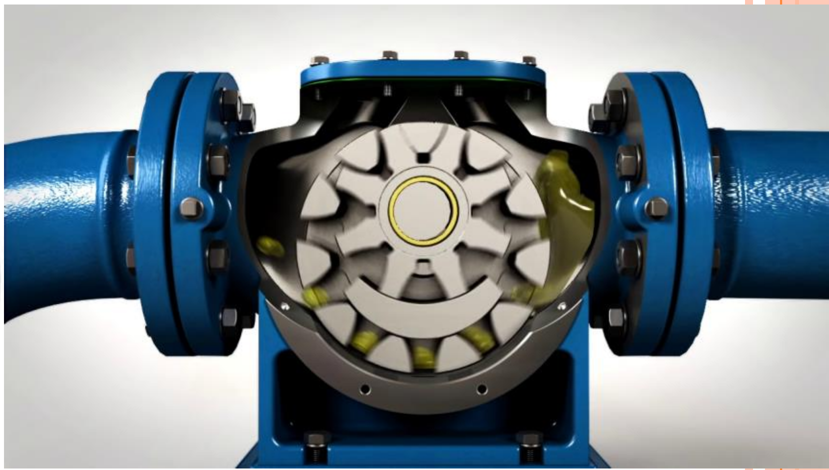
Internal Gear Pump:

Construction:

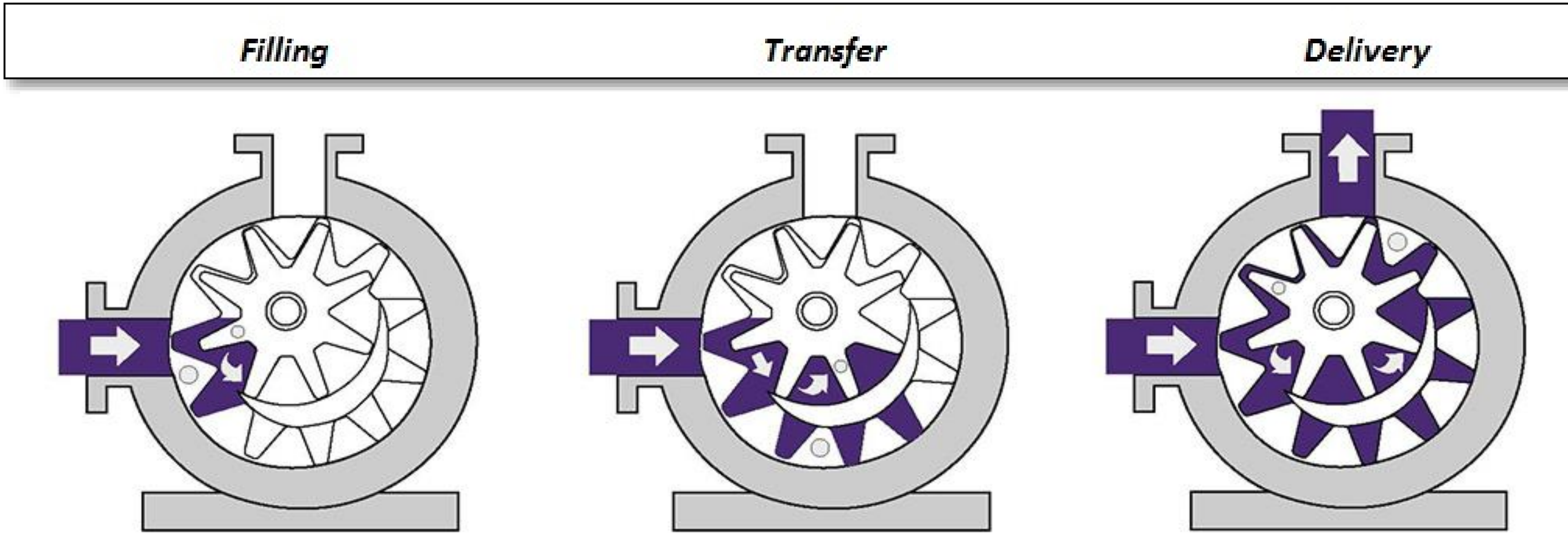
- An internal gear pump operates on the same principle but the two interlocking gears are of different sizes with one rotating inside the other.
- The larger gear (the rotor) is an internal gear i.e. it has the teeth projecting on the inside. Within this is a smaller external gear (the idler – only the rotor is driven) mounted off-centre.
- This is designed to interlock with the rotor such that the gear teeth engage at one point. A pinion and bushing attached to the pump casing holds the idler in position. A fixed crescent-shaped partition or spacer fills the void created by the off-centre mounting position of the idler and acts as a seal between the inlet and outlet ports.







WORKING:



1. As the gears come out of mesh on the inlet side of the pump, they create an expanded volume. Liquid flows into the cavities and is trapped by the gear teeth as the gears continue to rotate against the pump casing and partition.

2. The trapped fluid is moved from the inlet, to the discharge, around the casing.

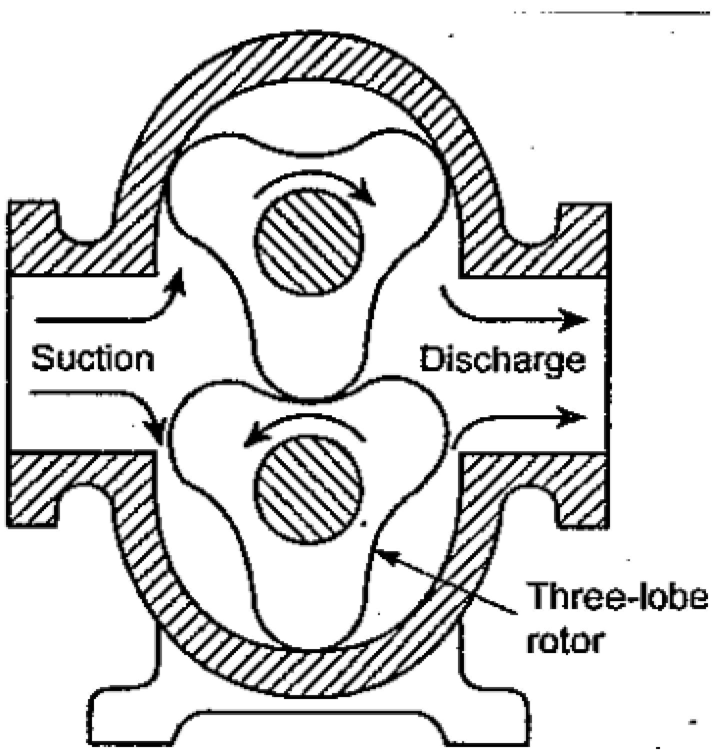
3. As the teeth of the gears become interlocked on the discharge side of the pump, the volume is reduced and the fluid is forced out under pressure.

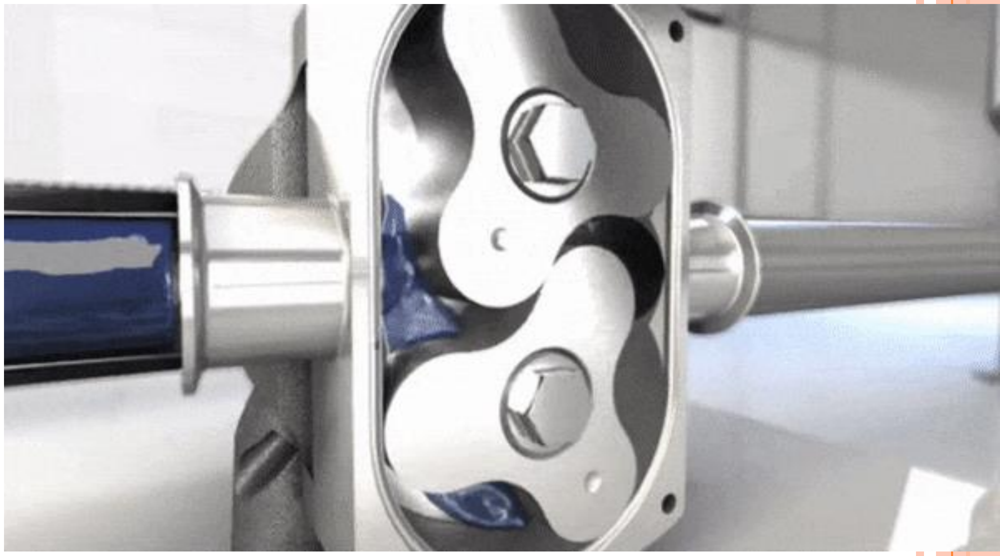
Internal Gear Pump Applications

- Used in surfactants and soaps manufacturing
- Pigments, inks, and resins
- Used in food products like animal feed, cocoa butter, corn soups and in many

Lobe Pump

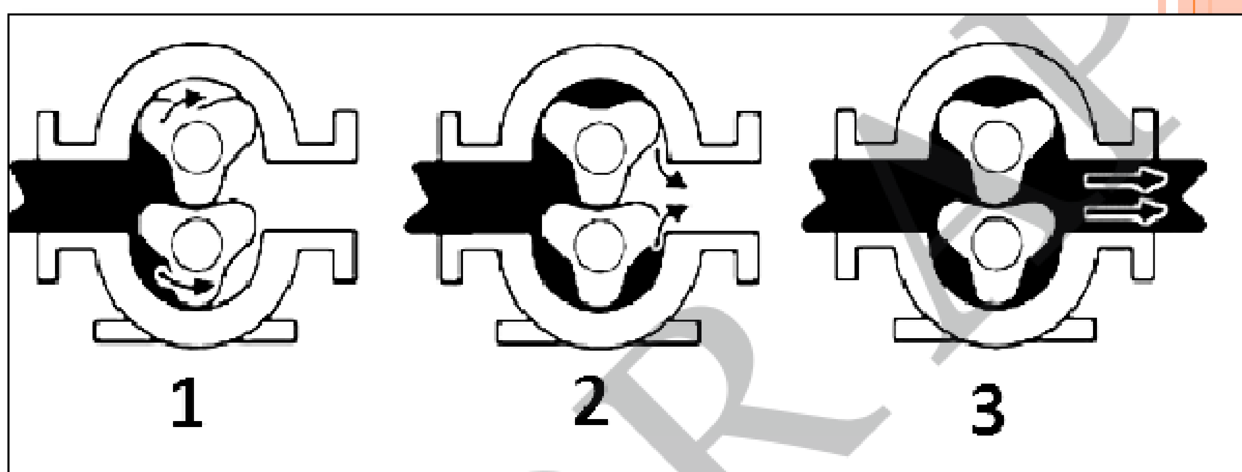
- The gears are replaced by the lobes.
- This pump operates in a similar fashion as that of external pump.
- But unlike the external gear pump, these both lobes are driven independently and they do not have actual contact with each other.





Working...

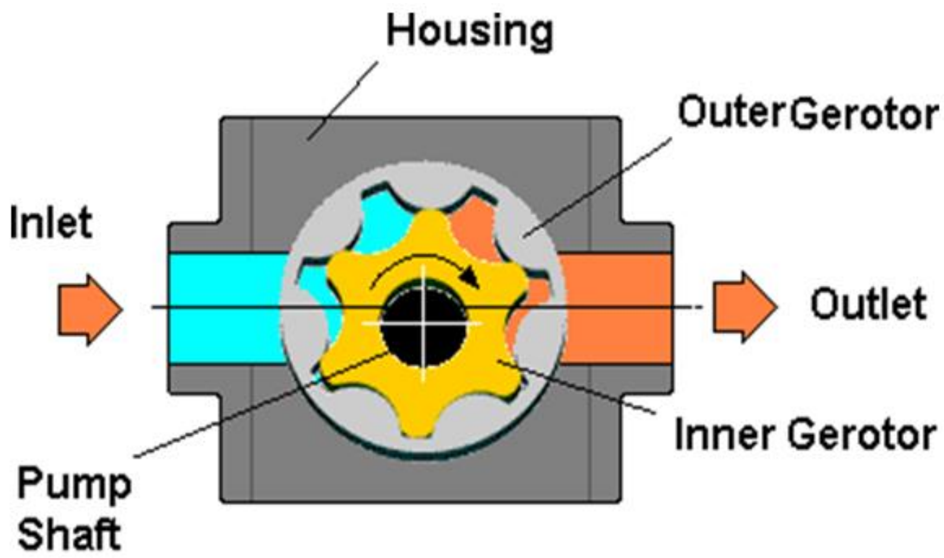
- As the lobes come out of mesh, they create expanding volume on the inlet side of the pump.
- Liquid flows into the cavity and is trapped by the lobes as they rotate.
- Liquid travels around the interior of the casing in the pockets between the lobes and the casing it does not pass between the lobes.
- Finally, the meshing of the lobes forces liquid through the outlet port under pressure.
- Used for pumping liquid, gas, and air with low pressure and high flow rate.

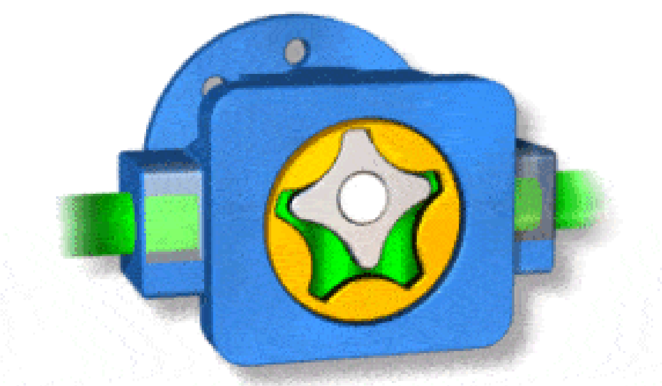


https://www.youtube.com/watch?v=1ca-rXDqMMo

Gerotor Pump

- Operates very similar to internal gear pump
- It consist of inner gerotor, outer gerotor and housing.
- The inner rotor has N teeth, and the outer rotor has N+1 teeth.
- The inner rotor is located off-center and both rotors rotate.





WORKING...

- During part of the assembly's rotation cycle, the area between the inner and outer rotor increases, creating a vacuum.
- This vacuum creates suction, and hence, this part of the cycle is where the intake is located.
- Then, the area between the rotors decreases, causing compression.
- During this compression period, fluids can be pumped, or compressed.
- During the compression period, the exhaust is pumped out.

Advantages

- High Speed
- Only two movingparts
- Constant and even discharge regardless of pressure conditions
- Operates well in either direction
- Quiet operation

Disadvantages

- Medium pressure limitations
- Fixed clearances
- No solids allowed
- One bearing runs in the product pumped
- Overhung load on shaft bearing

Applications

Light fuel oils

Lube oil

Cooking oils

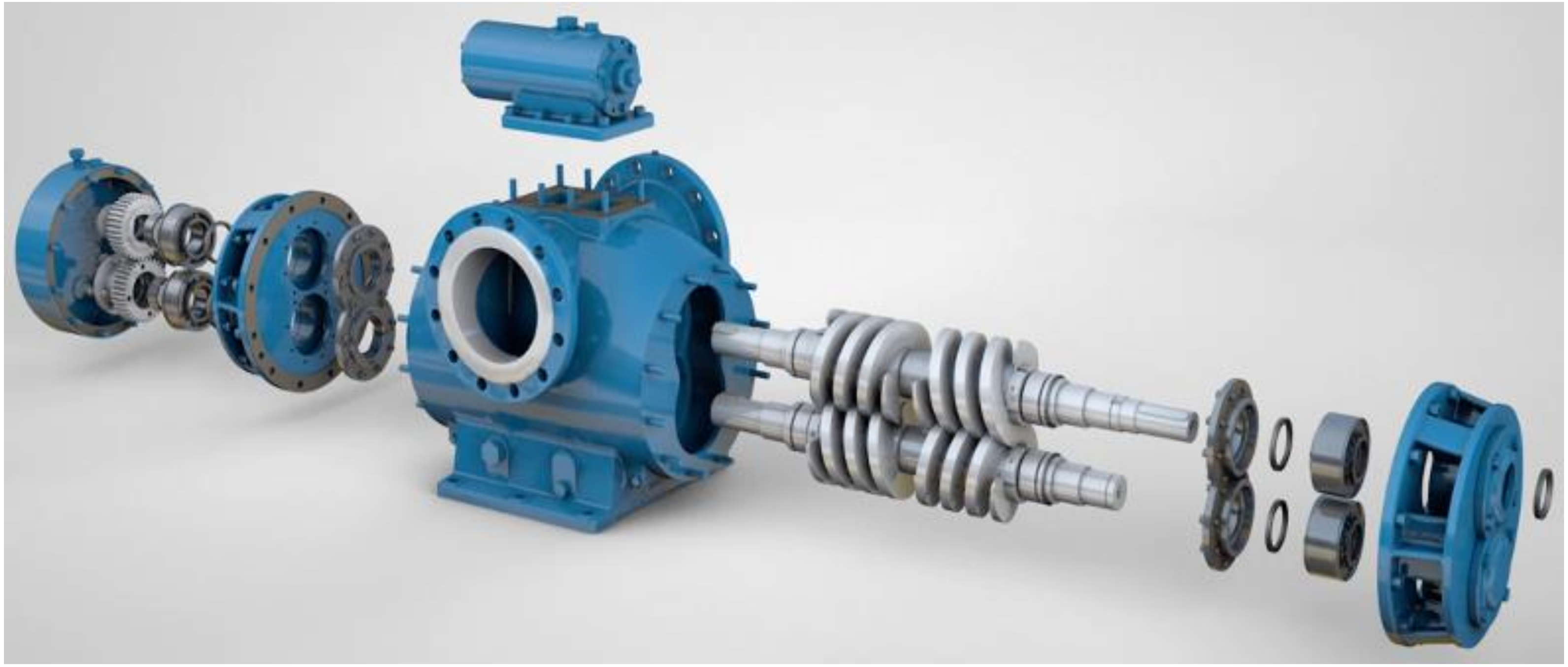
Hydraulic fluid

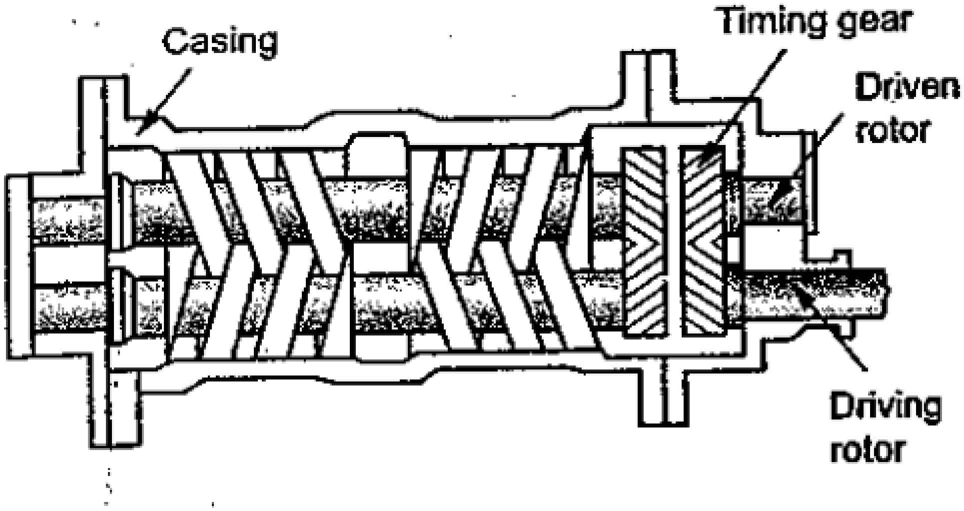
SCREW PUMP

- It is an axial flow positive displacement unit.
- Screws are meshing within a close fitting housing, deliver non pulsating flow quietly and efficiently.
- The two symmetrically opposed idler rotors act as rotating seals, confining the fluid in a succession of closures or stages.

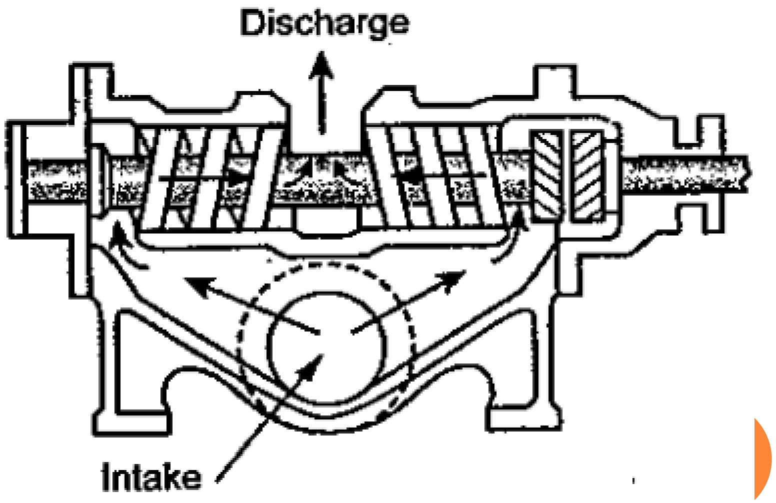
Operation:

- The liquid is entered at the two ends and discharged at the centre.
- The pumping action comes from the sealed chamber
- Sealed chamber formed by the contact of the two gears at the interaction of their addenda and by the small clearance between the screw and the pump housing.
- The liquid moves forward along the axis with the rotation of the screw and its discharge to the outlet port.





(a) Top view



(b) Side view

Advantages:

1. Give uniform pressure with negligible pulsations.
2. Very quiet, because of rolling action of the screw spindles.
3. Can handle liquids containing vapour and gases

Disadvantages:

1. It is difficult to manufacture the screw profile to maintain close tolerance.
2. Overall volumetric and mechanical efficiency is relatively low.

https://www.youtube.com/watch?v=XcvIDog5cZs

Vane Pump

- The major problem in gear pumps is that the significant amount of leakage occurs between the small gaps of teeth, and also between teeth and pump housing.
- The vane pumps reduce this leakage by using spring or hrdraulic loaded vanes.

Types of Vane Pumps:

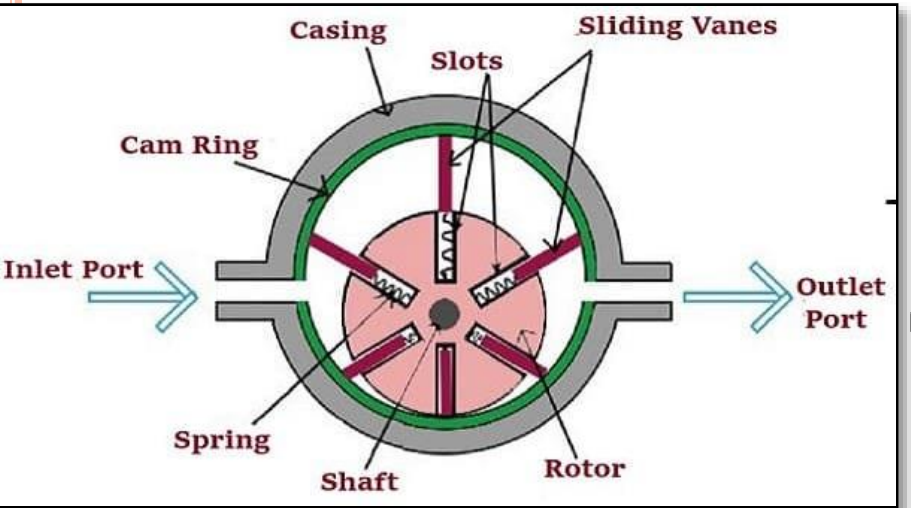
1. Unbalanced Vane Pumps

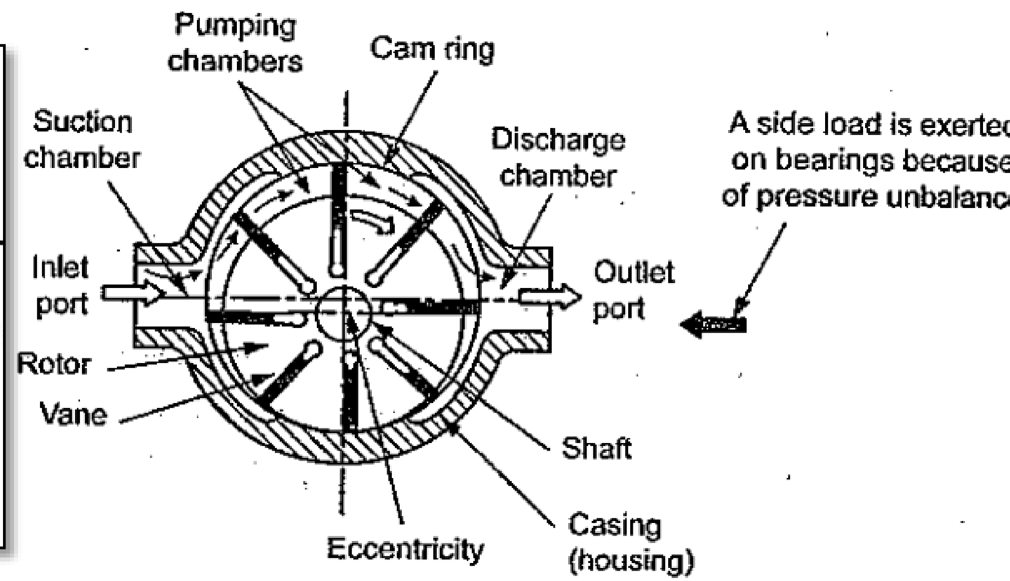
    a. Fixed displacement unbalanced pumps

    b. Variable displacement unbalanced pumps

2. Balanced Vane Pumps

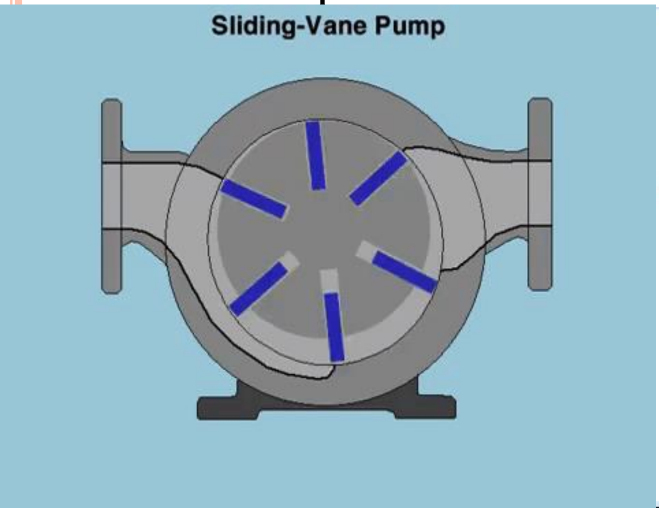
1. Unbalanced Vane Pump

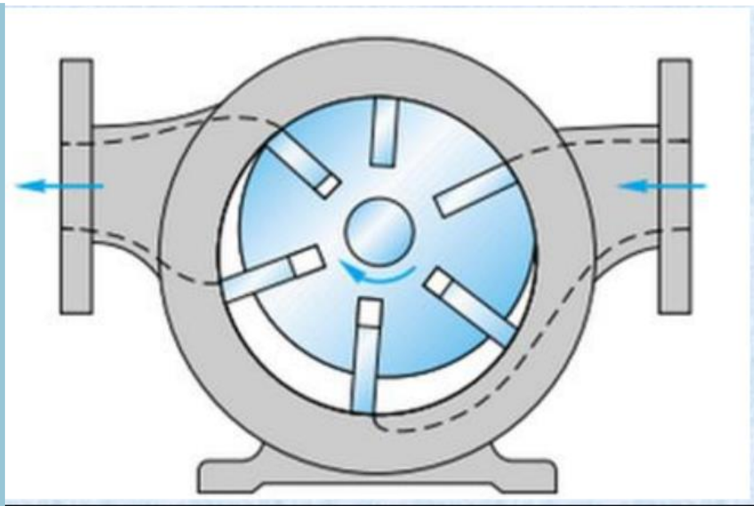


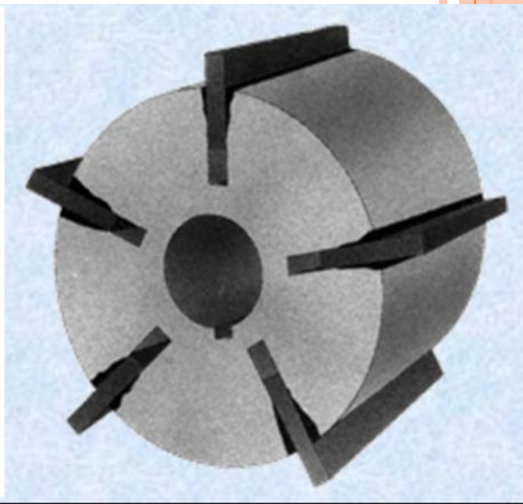


- The pump consists of a rotor which contains radial slots splined to the drive shaft. The rotor rotates inside a cam ring.
- Each slot contains a vane which is free to slide in or out of the slots in the pump rotor.
- The vane is designed to mate with the surface of the cam ring as the rotor turns. As the rotor rotates, the centrifugal force pushes the vanes out against the surface of the cam ring.
- The vanes divide the space between the rotor and the cam ring into a series of small chambers.

- cam ring into a series of small chambers. During the first half of rotor rotation, the volume of these chambers increase, thereby causing a reduction of pressure. This is the **suction process** which causes the fluid to flow through the inlet port and fill the void.
- As the rotor rotates through the second half, the cam ring pushes the vane back into their slots and the trapped volume is reduced. This positively ejects the trapped fluid through the outlet port.

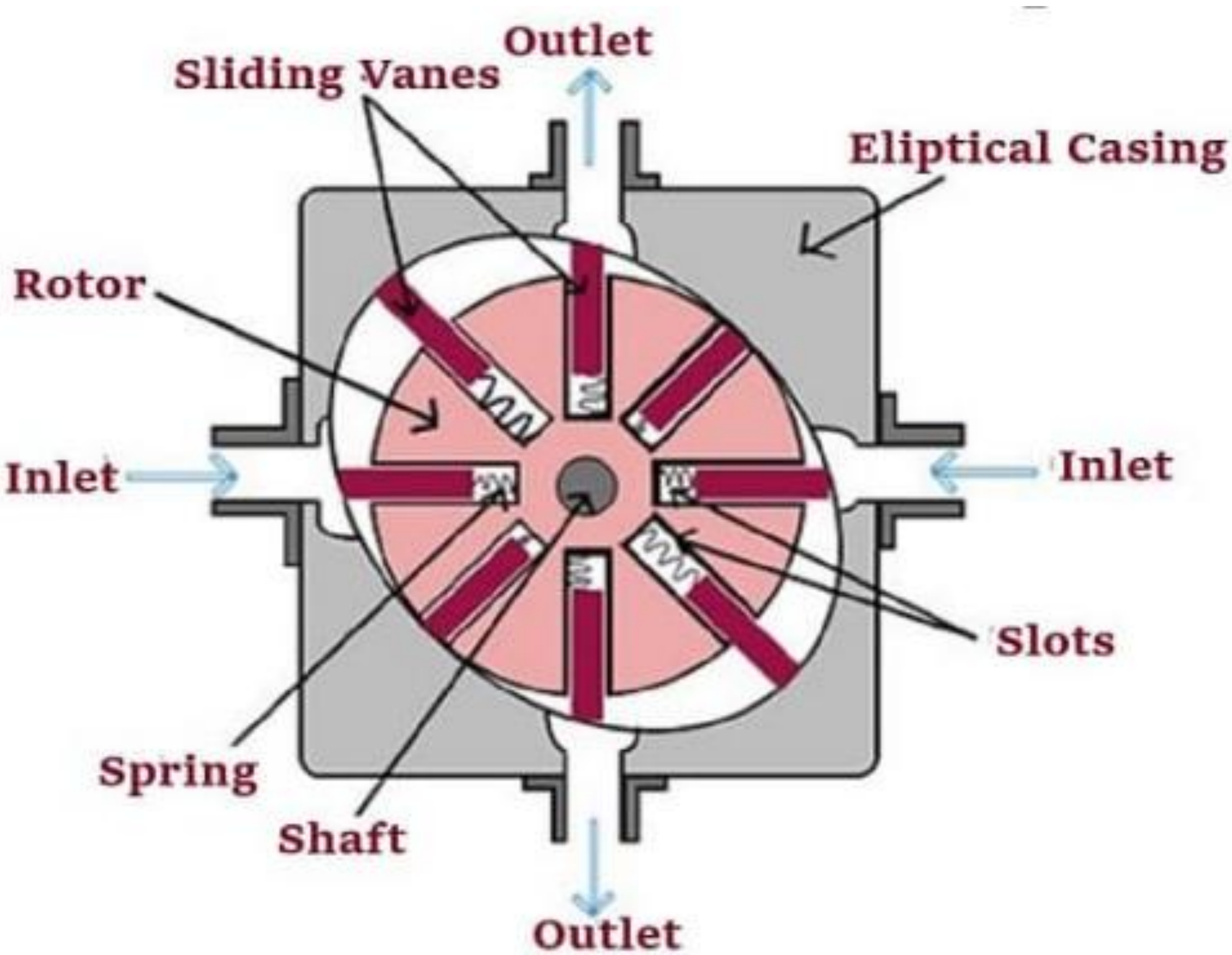




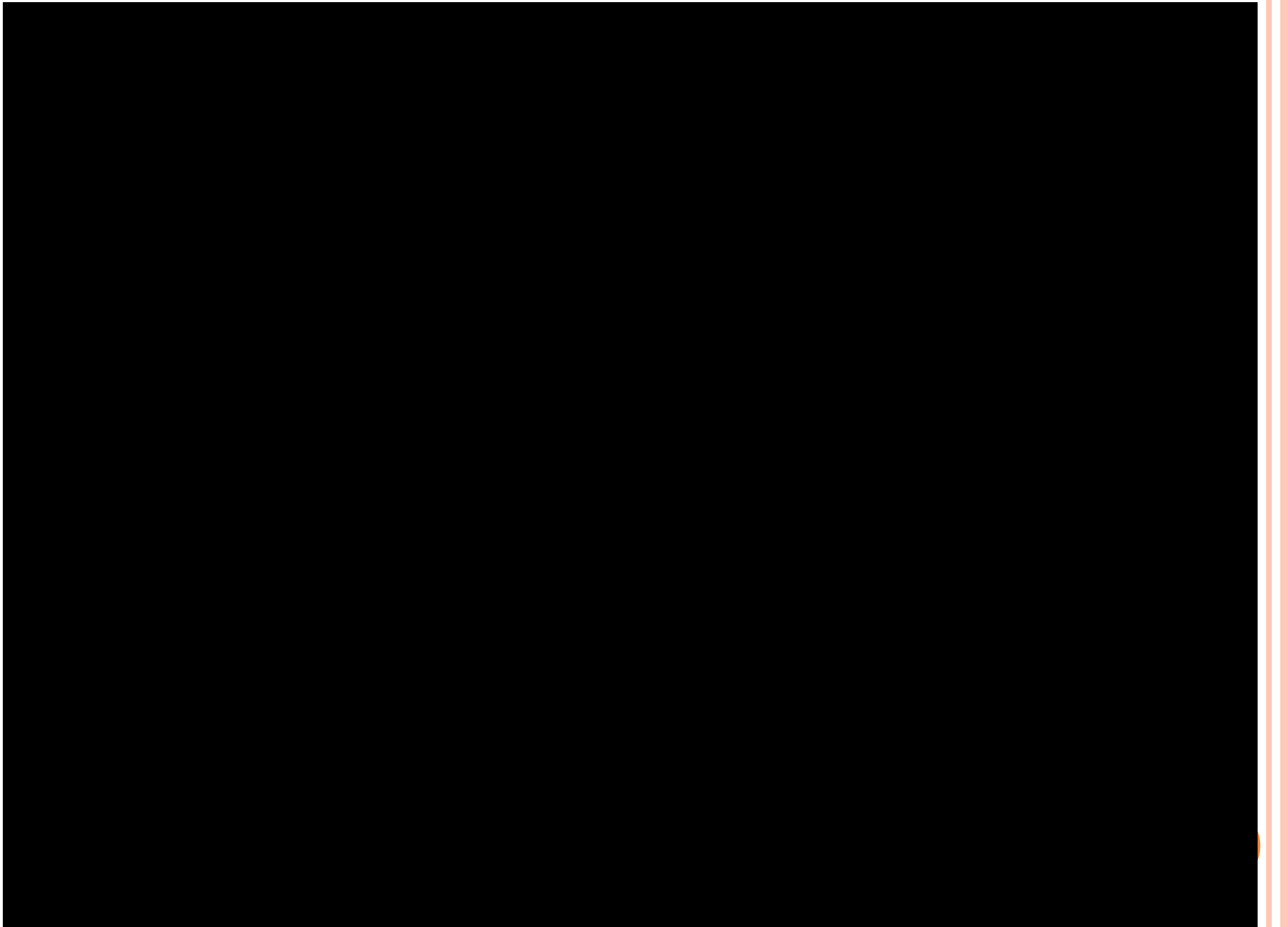


- https://www.youtube.com/watch?v=sXxRvD-B9z8
- https://www.youtube.com/watch?v=BnvzPoNSXCg

2. Balanced Vane Pump



- https://www.youtube.com/watch?v=b0_bGKHHHPM



- The balanced rotary vane pump has an elliptical casing. The elliptical casing and rotor have the same centre. There is no offset.
- These vane pumps are versatile in design and most widely used in mobile and industrial applications.
- The pressure difference doesn’t create between the inlets and outlets because this pump has two inlets and an outlet.
- The two inlet ports are on opposite sides of each other. Similarly, the outlet ports are also on opposite sides.
- This assembly of the inlet and outlet ports balance equal and opposite thrust forces so that the rotor shaft doesn’t face any lateral thrust forces.

- This balance pump offers better performance and long service life.
- This type of pump has a perfect service life in many applications. In industrial applications, the balance vane pumps have more than 24,000 hours of service life.
- The cavity size between two vanes decreases from inlet side to outlet.
- The pump sucks fluid from the inlet port while discharges from the outlet port.
- The pressure acting on the rotor in the exit area is high; the forces in the two outlet areas are equal but opposite. Therefore, there is no net load on the bearings of the shaft.

Advantages

1- Handles thin liquids at relatively higher pressures

2- Compensates for wear through vane extension

3- Can run dry for short periods

4- Can have one seal or stuffing box

5- Develops good vacuum

Disadvantages

1- Complex housing and many parts

2- Not suitable for high pressures

3- Not suitable for high viscosity

Piston Pump

- The pumping action is affected by a piston that moves in a reciprocating cycle through a cylinder. These pumps are classified as

  1. **Axial Piston Pumps**

     a. Swash plate axial piston pump

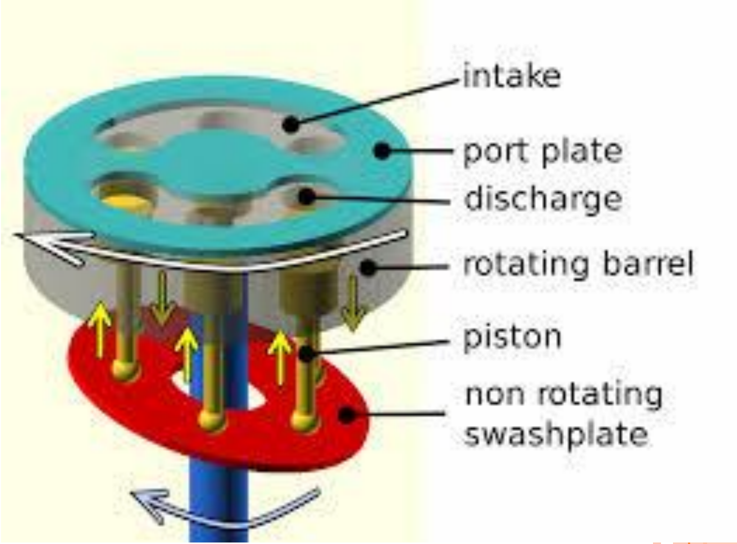
     b. Bent axis Axial piston pump

  2. **Radial Piston Pumps**

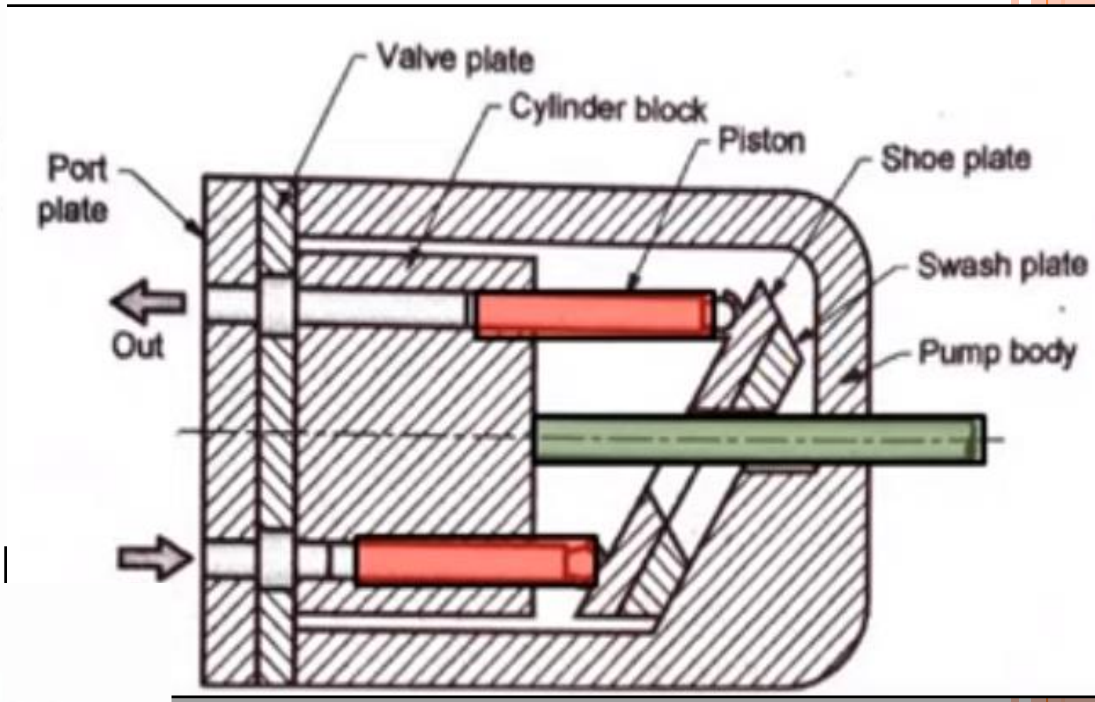
- In **axial piston** pumps, a number of pistons and cylinders are located in a parallel position with respect to the drive shaft, while in the **radial type** they are arranged radially around the rotor hub.

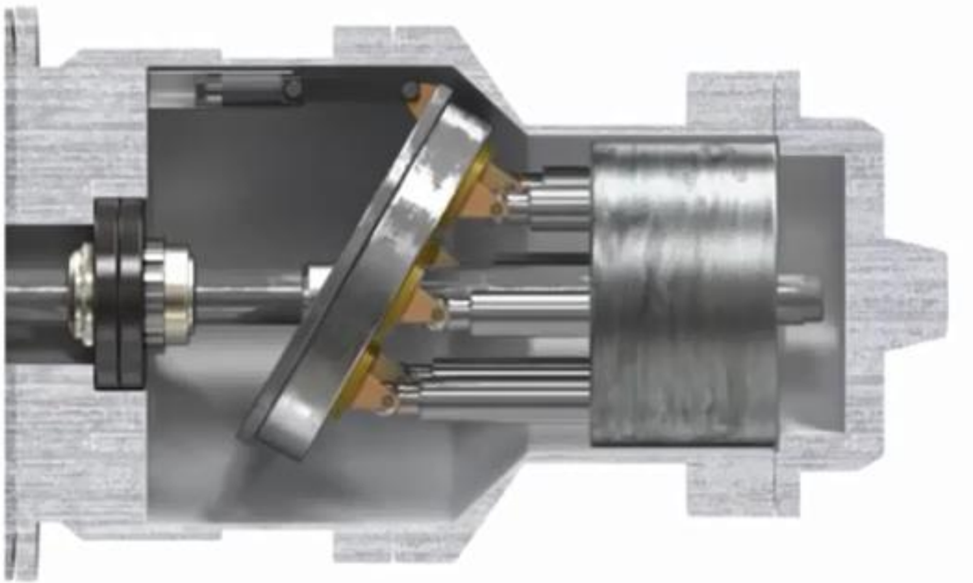
1. Axial Piston Pump

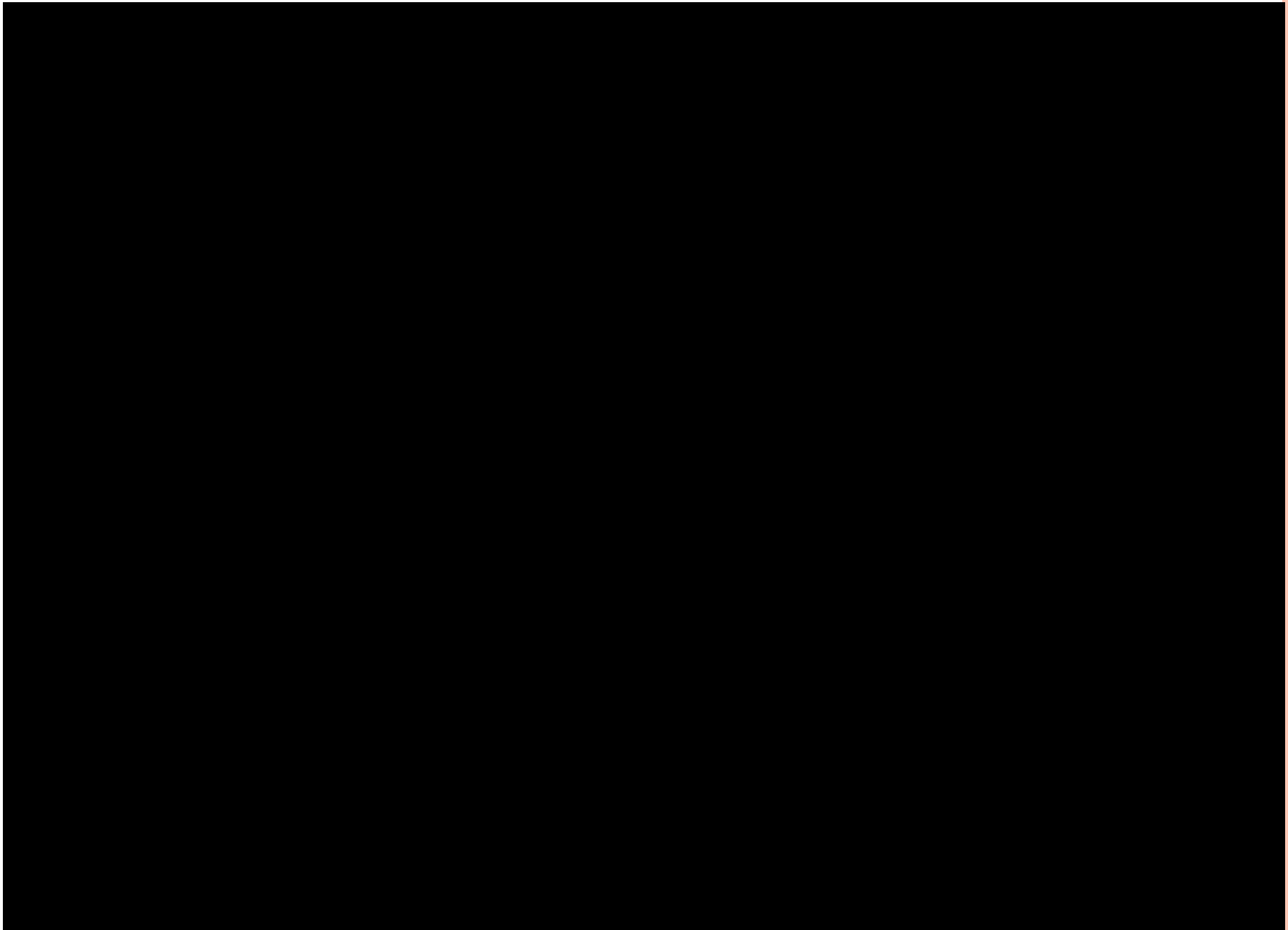
- Rotary shaft motion is converted to axial reciprocating motion which drives the piston.
- Most axial piston pumps are multi piston designs and utilize check valves or port plates to direct liquid flow from inlet to discharge.
- Output can be controlled by manual, mechanical or pressure compensated controls.



A. Swash plate axial piston pump



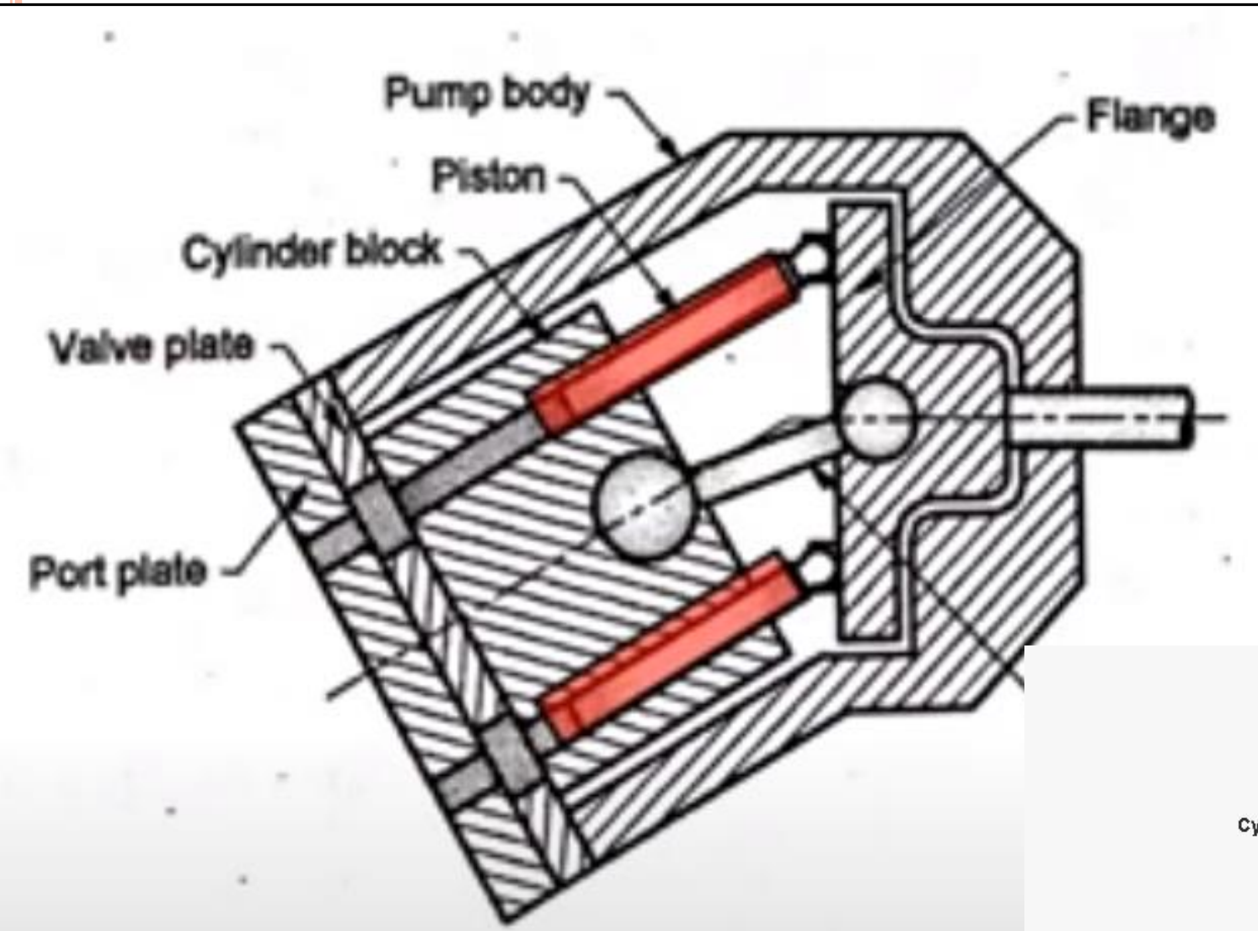


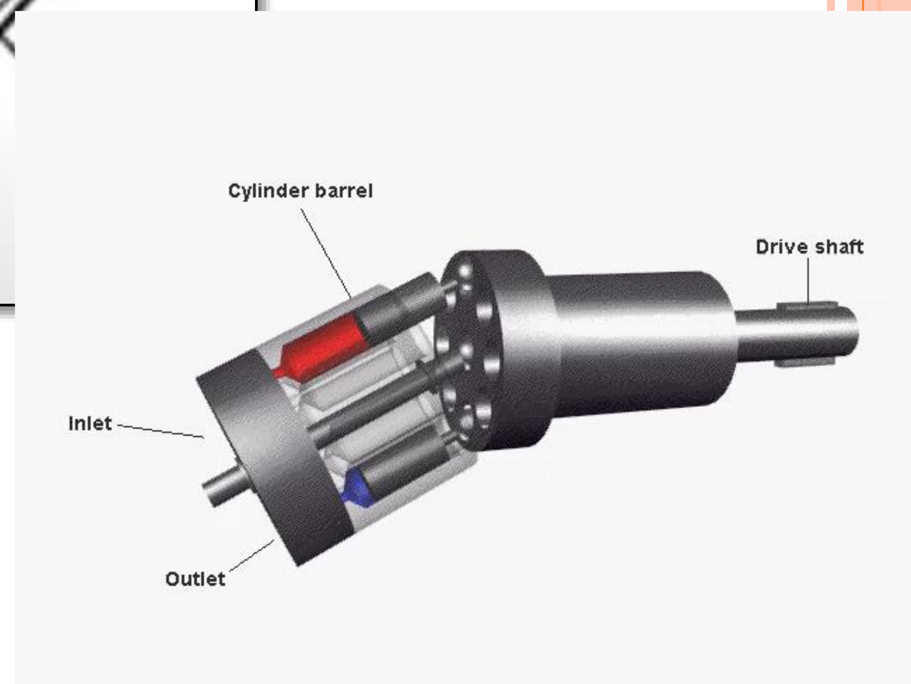


Swash plate axial piston pump

- The cylinder block is fitted to the drive shaft, i.e. The axis of rotation of rotation cylinder block and the drive shaft are same.
- The shoe plate is mounted on **a swash plate**, which is fixed at an angle to the axis of rotation.
- The **angle of swash plate** can be varied to change the speed of the motor.
- When working fluid is supplied to the inlet, it exerts force on the pistons, due to which cylinder block rotates, shaft rotates and working fluid comes out from the outlet.

B. Bent axis Axial piston pump

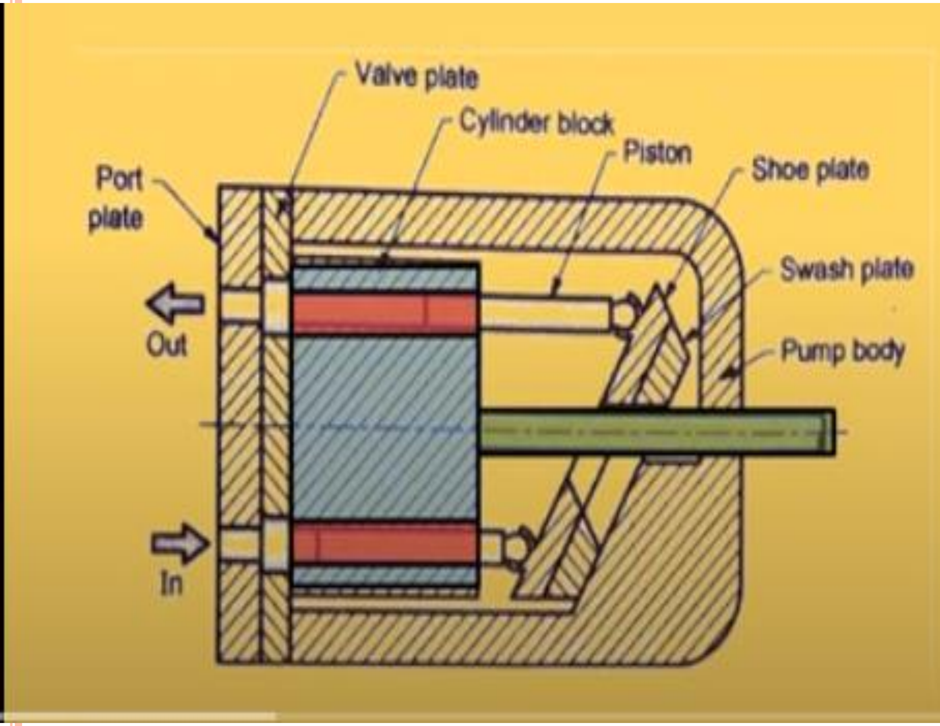




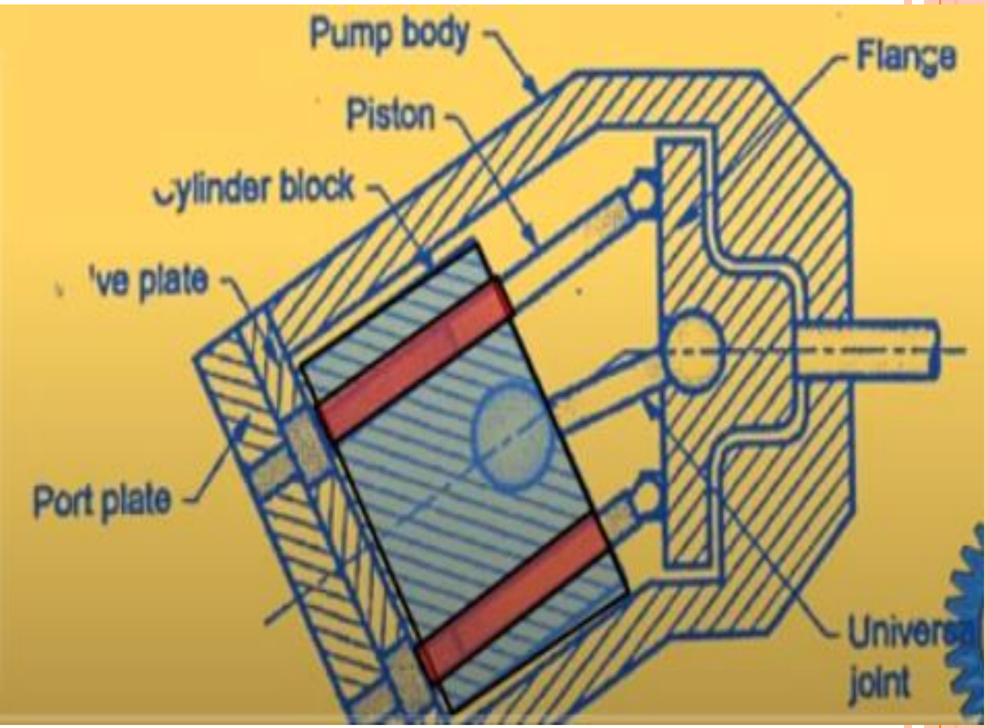
[redacted]

- It consists of a cylinder block with axial bores.
- Pistons are inserted in these bores. The other ends of the pistons are connected to the shoe plate with shoe joints (spherical joints).
- In bent axis piston pump shown in Fig, the shoe plate is fixed to a flange; the flange is keyed to a drive shaft.
- The axis of cylinder block and flange are intersecting at an angle.
- A universal link couples the flange and the cylinder block.
- When the shaft is rotated, it causes the cylinder block to rotate, the shoe plate will also rotate with it, causing the pistons in the bores to reciprocate.
- Half rotation of the cylinder block causes suction of oil into a bore and the next half rotation causes discharge.
- There are 8 or 12 number of such bores, which are continuously performing suction and discharge in proper order; hence the pump discharge is smooth and continuous.

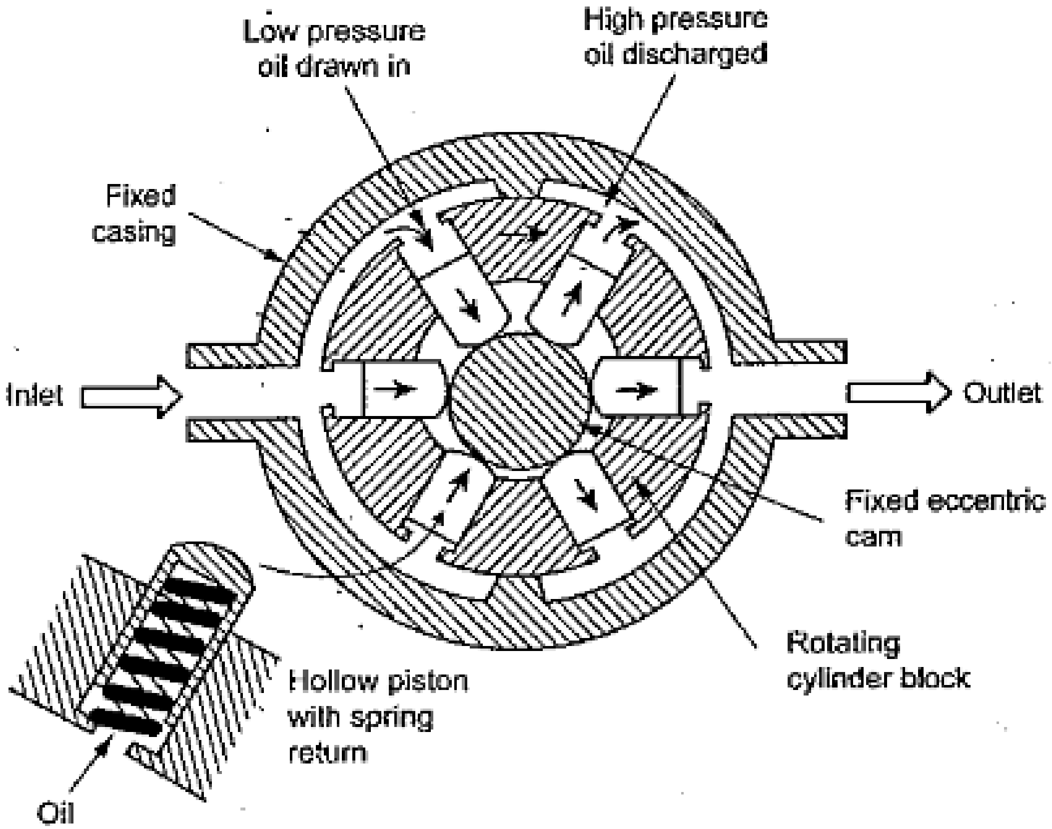
Swash plate axial piston pump



Bent axis Axial piston pump



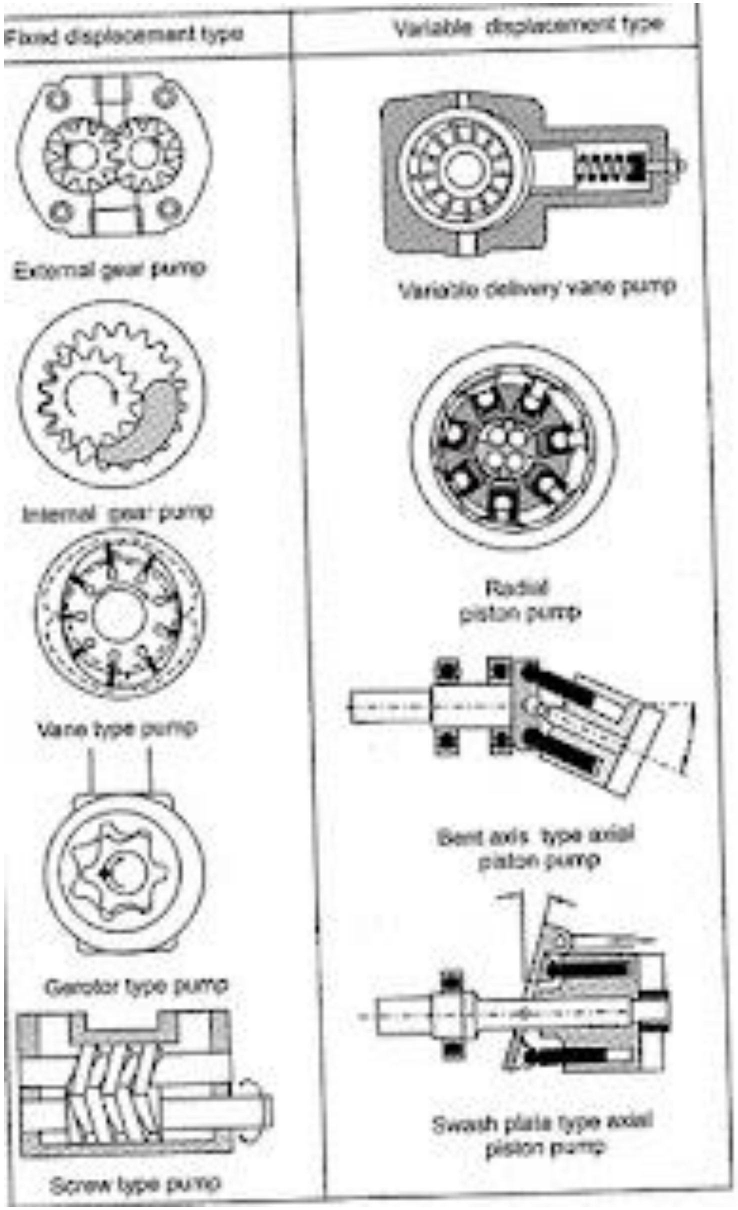
Radial Piston Pumps

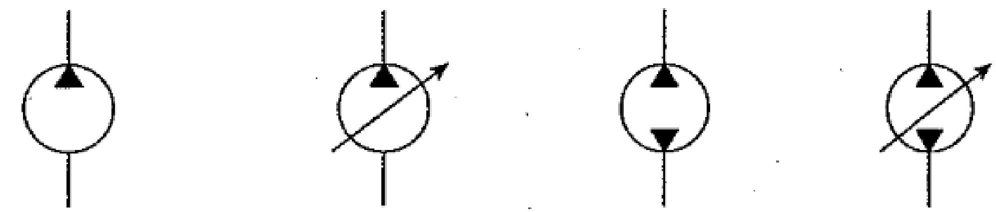


The radial piston pump has a number of radial pistons (in similar fashion to the spokes of a wheel) in a cylinder block which revolves around a stationary eccentric cam. In these pumps, the pistons move perpendicularly to the shaft centerline. As the cylinder block rotates, the eccentricity of the cam causes an in-and-out or pumping motion of the pistons. This

Rotating Cylinder Radial Piston Pump:

- Rotating Cylinder Radial Piston Pump is shown in Fig.
- This pump consists of rotating cylinder block, which is mounted with an offset inside a casing.
- The casing has a reaction ring with which, the pistons remains in contact while the cylinder block is rotating. This is achieved by centrifugal force and pressure of liquid.
- The pistons are assembled inside the radial bores of the cylinder block; inlet port and outlet port are located at the centre.
- The inlet port and outlet ports are separated by pintle. As the cylinder block rotates, piston will reciprocate in their bores.
- This causes suction of oil during first half of rotation and discharge during the next half.
- There are 8 to 12 number of such bores, which are continuously performing suction and discharge in proper order; hence the pump discharge is smooth and continuous.





(a) *Fixed displacement, unidirectional pump*

(b) *Variable displacement unidirectional pump*

(c) *Fixed displacement, bidirectional pump*

(d) *Variable displacement bidirectional pump*

Pump Performance

1. **Volumetric Efficiency**

   Ratio between actual flow rate produced by pump and the theoretical flow rate that the pump produced.

$$\text{Volumetric efficiency} = \frac{\text{Actual flow rate produced by the pump}}{\text{Theoretical flow rate that the pump should produce}} \times 100$$

$$\eta_{vol} = \frac{Q_A}{Q_T} \times 100 \qquad \ldots (5.10)$$

2. Mechanical Efficiency

Ratio between the theoretical power required to operate the pump and the actual power delivered to the pump.

$$\text{Mechanical efficiency} = \frac{\text{Theoretical power required to opeate the pump}}{\text{Actual power delivered to pump}} \times 100 \qquad \ldots (5.11)$$

or

$$\eta_{mech} = \left(\frac{P \times Q_T}{T_A \times \omega}\right) \times 100 \qquad \ldots (5.12)$$

3. Overall Efficiency

It is the ratio between the actual power delivered by pump and the actual power delivered to pump.

✓ ***Formula :***

$$\text{Overall efficiency} = \frac{\text{Actual power delivered by pump}}{\text{Actual power delivered to pump}} \times 100 \quad \text{... (5.16)}$$

Mathematically, the overall efficiency can also be written as

$$\eta_0 = \text{Volumetric efficiency} \times \text{Mechanical efficiency}$$

or

$$\eta_0 = \eta_{vol} \times \eta_{mech} \quad \text{... (5.17)}$$

Substituting equations (5.10), (5.12), and (5.17), we get

$$\boxed{\eta_0 = \left(\frac{P \cdot Q_A}{T_A \cdot \omega}\right) \times 100} \quad \text{... (5.18)}$$

HYDRAULIC ACTUATORS

- It is a device used for converting hydraulic energy into mechanical energy. The pressurized hydraulic fluid delivered by the hydraulic pump is supplied to the actuators, which converts the energy of the fluid into mechanical energy. This mechanical energy is used to get the work done.

- **TYPES OF ACTUATORS:**

1. Linear Actuators (Hydraulic cylinders)
2. Rotary Actuators (Hydraulicmotors)
   a. Continuous rotary actuators
   b. Semi rotary actuators

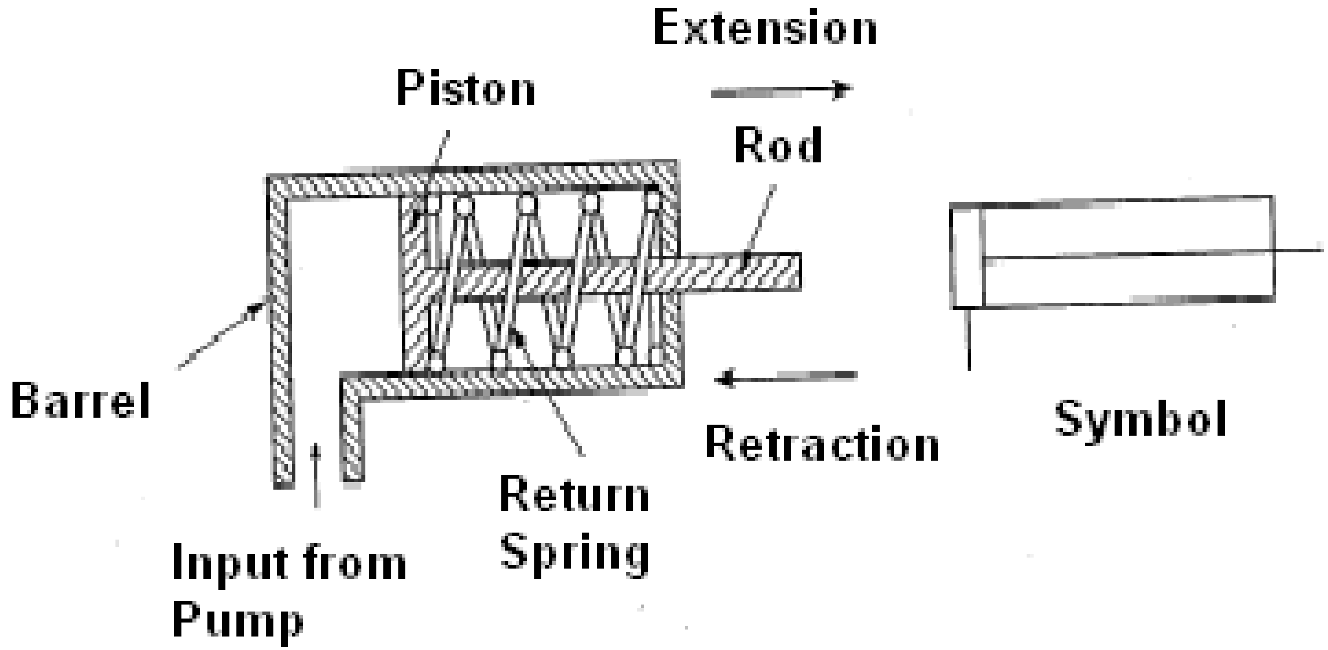
HYDRAULIC CYLINDERS:

- A hydraulic cylinder is a device, which **converts fluid power into linear mechanical force and motion**. It usually consists of a movable element, a piston and a piston rod operating within a cylinder bore.

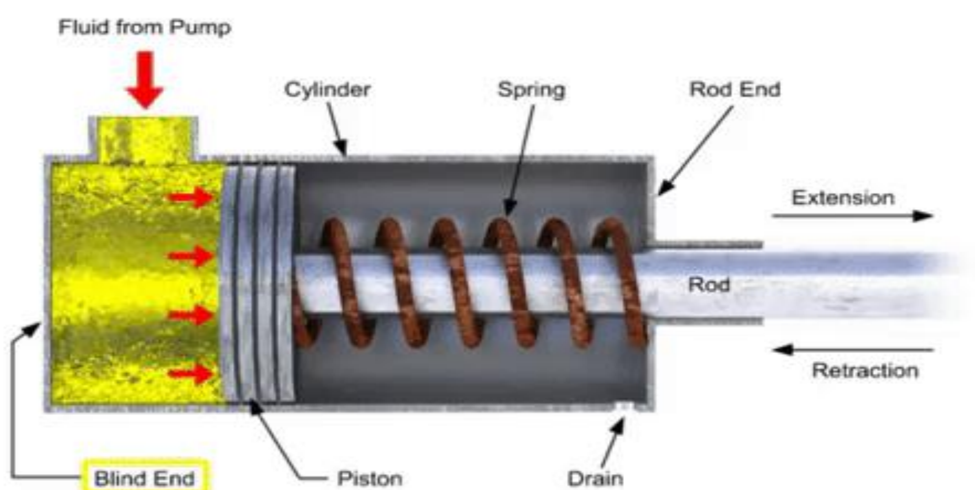
- TYPES OF HYDRAULIC CYLINDERS:

1. Single acting cylinders
2. Double acting cylinders
3. Telescoping cylinders
4. Double rod cylinder
5. Tandem cylinder

1. SINGLE ACTING CYLINDER:

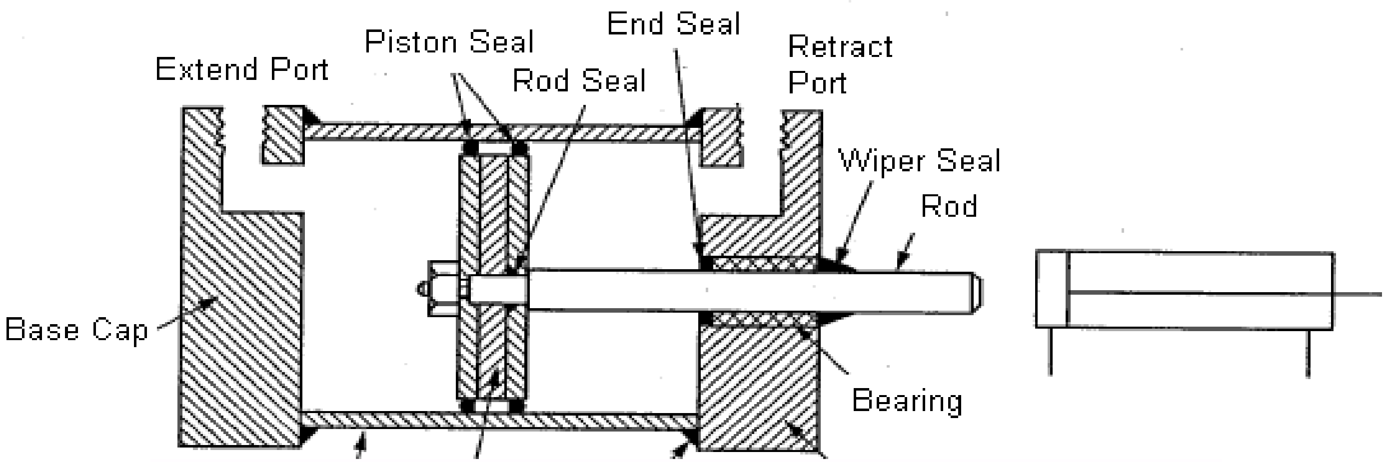


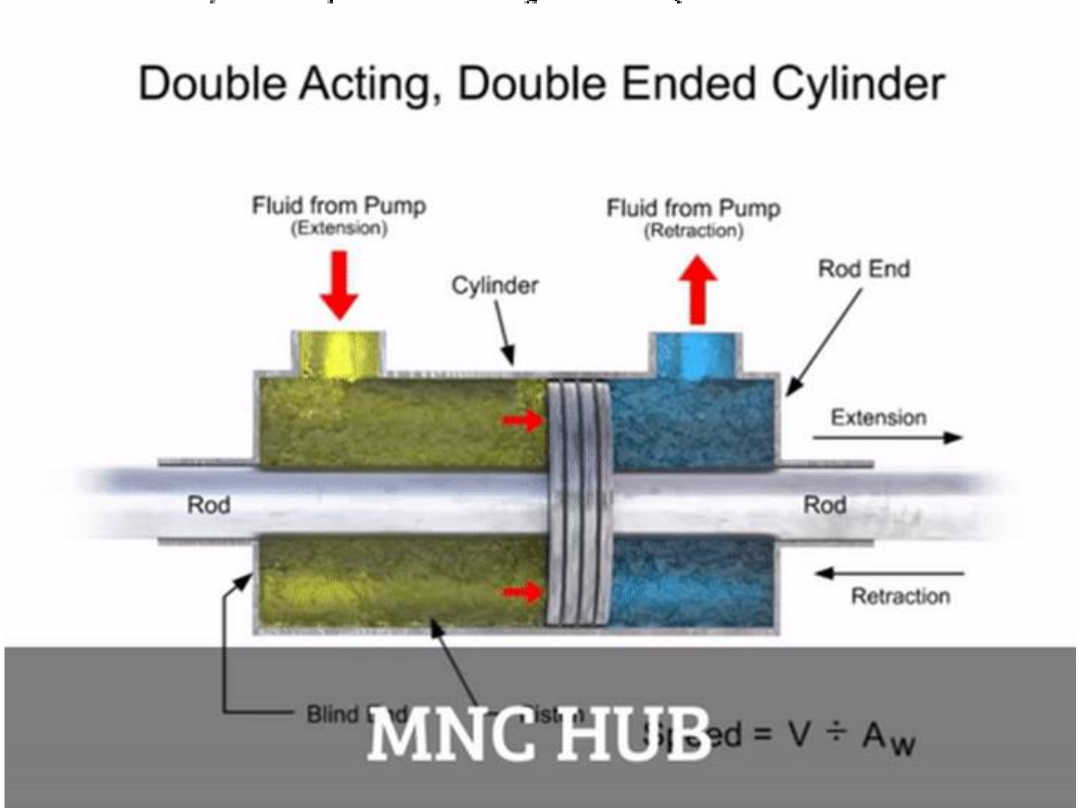
Single Acting, Single ended Cylinder



- A single acting cylinder is designed to apply force in only one direction. It consists of a piston inside a cylindrical housing called barrel. Attached to end of the piston is a rod which extends outside.
- At the other end (Blank end) is a port for the entrance and the exit of oil. A single acting cylinder can exert a force only in the extending direction, as fluid from the pump enters through the blank end of the cylinder.
- Retraction is accomplished by using gravity or by the inclusion of a compression spring at the rod end.
- **Advantages and Disadvantages:**
  1. The single acting cylinders are very simple to operate, and compact in size.
  2. The single acting cylinders with spring return cannot be used for larger stroke length.

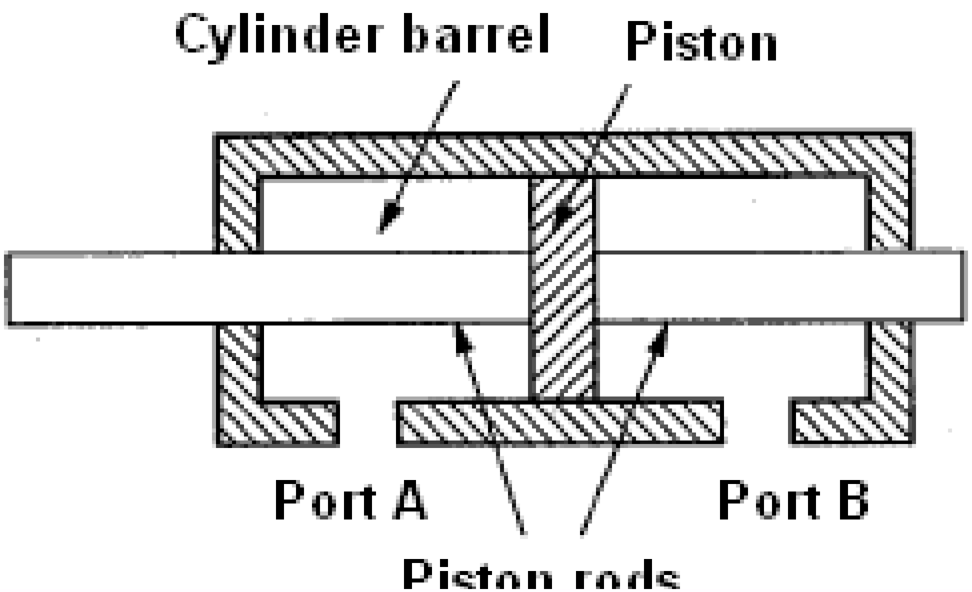
2. DOUBLE ACTING CYLINDER

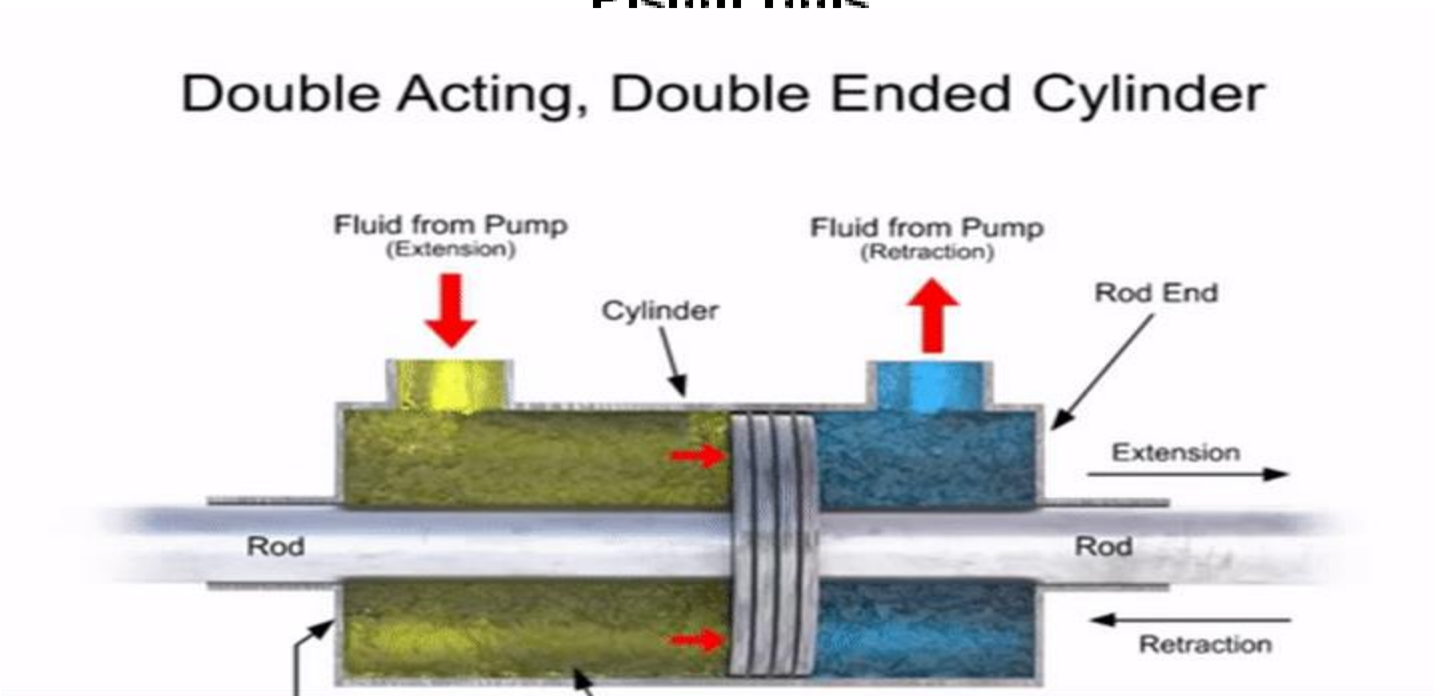




- A double acting cylinder is capable of delivering forces in both directions.
- The barrel is made of seamless steel tubing, honed to affine finish on the inside surface.
- When the fluid from the pump enters the cylinder through port 1, the piston moves forward and the fluid return to the reservoir from the cylinder through port 2.
- During the return stroke the fluid is allowed to enter the cylinder through port 2 and fluid from the other side of the piston goes back to the reservoir through port 1.

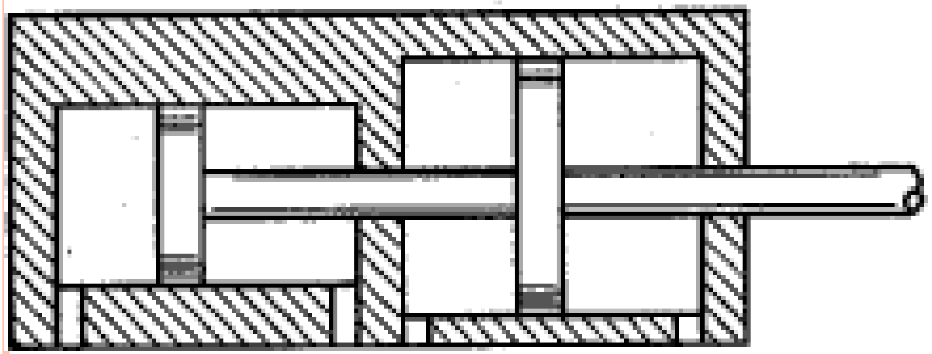
DOUBLE ROD CYLINDER

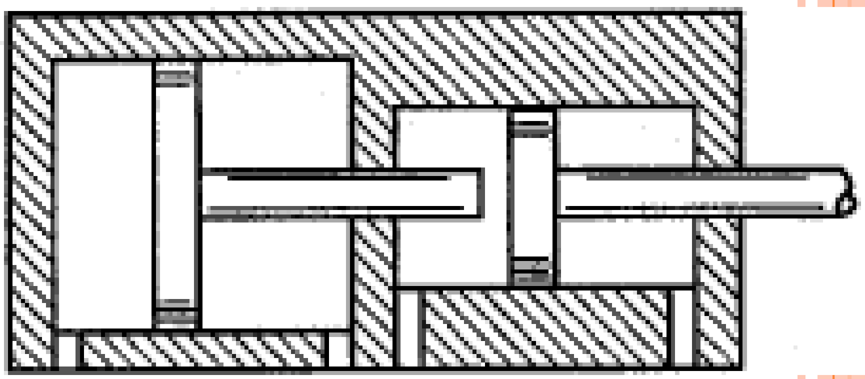


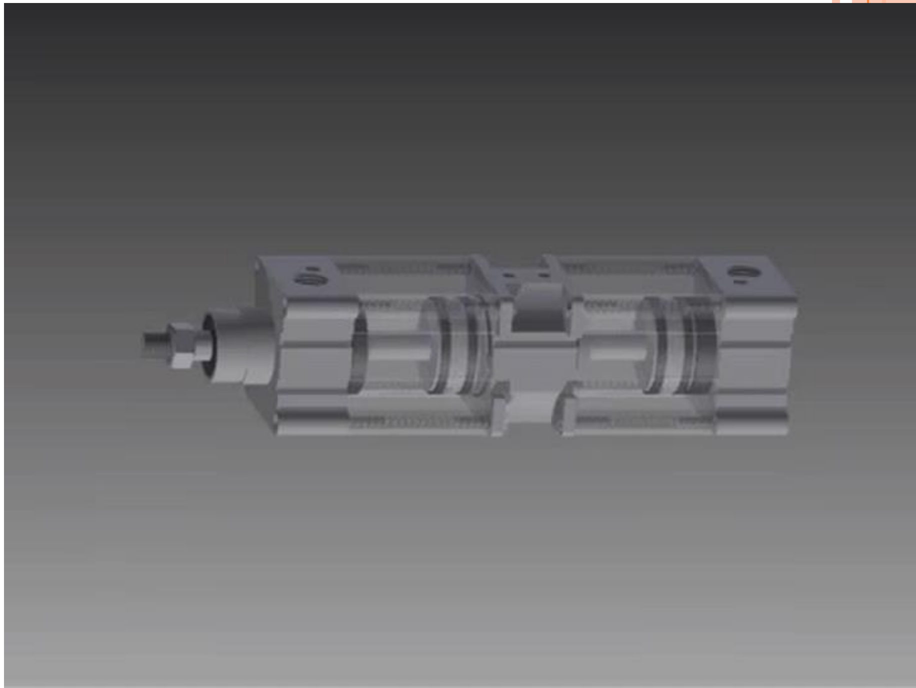


- It is a cylinder with single piston and a piston rod extending from each end.
- This cylinder allows work to be performed at either or both ends.
- It may be desirable where operating speed and return speed are equal.

TENDAM CYLINDER

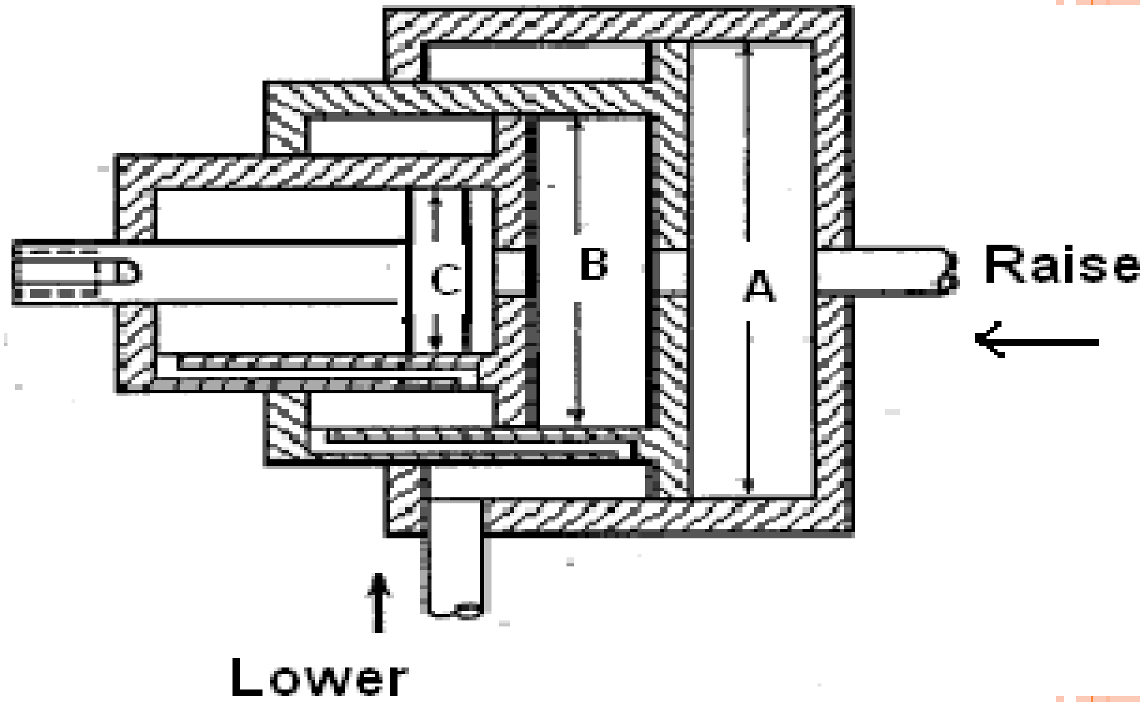


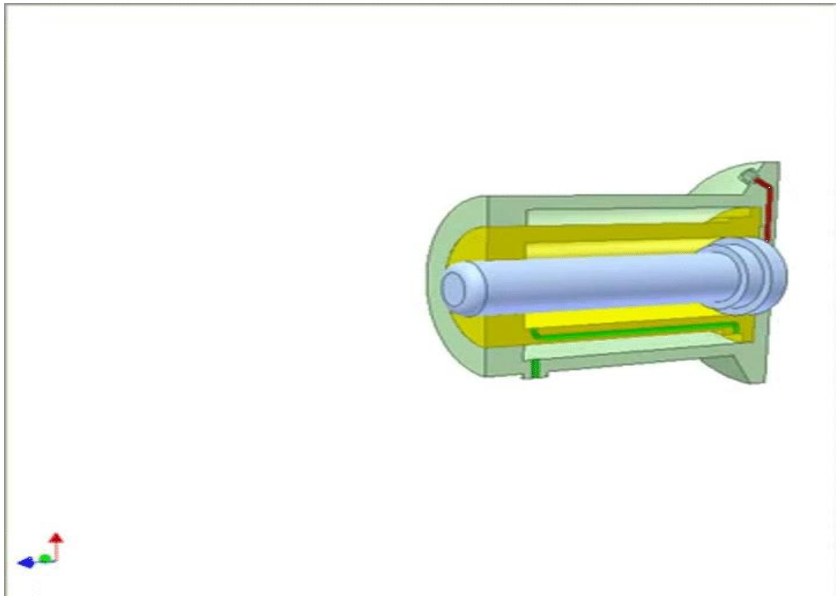




- It design has two cylinders mounted in line with pistons connected by a common piston rod.
- These cylinders provide increased output force when the bore size of a cylinder is limited.
- But the length of the cylinder is more than a standard cylinder and also requires a larger flow rate to achieve a speed because flow must go to both pistons.

TELESCOPING CYLINDER

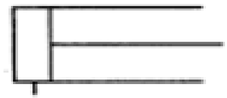




- They are used where long work strokes are needed.
- The diameter A of the ram is relatively large, this ram produces a large force for the beginning of the lift of the load. When ram A reaches the end of the stroke, ram B begins to move.
- Now ram B provides the required smaller force to continue raising the load. When ram B reaches the end of its stroke, then ram C moves outwards to complete the lifting operation.
- These three rams can be retracted by gravity acting on the load or by pressurized fluid acting on the lip of each ram.

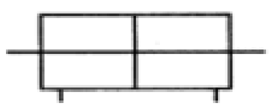
GRAPHIC SYMBOLS FOR LINEAR ACTUATORS:

Double Acting Cylinder

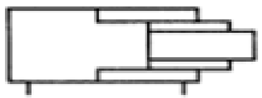


Single Acting Cylinder

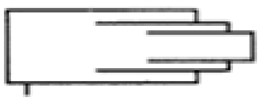
Single Acting with Spring return



Double Rod Double Acting



Telescopic Double Acting



Telescopic Single Acting

Rotary Actuators

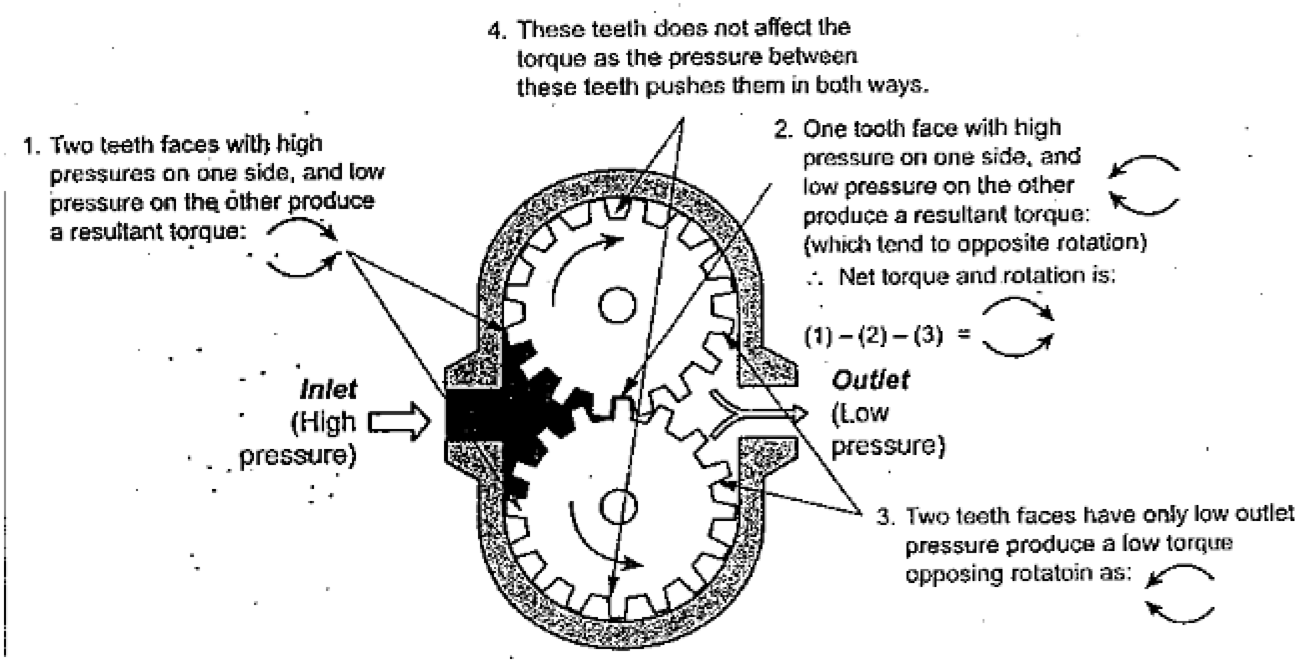
The hydraulic motors can be classified based on their degree of angular movement as :

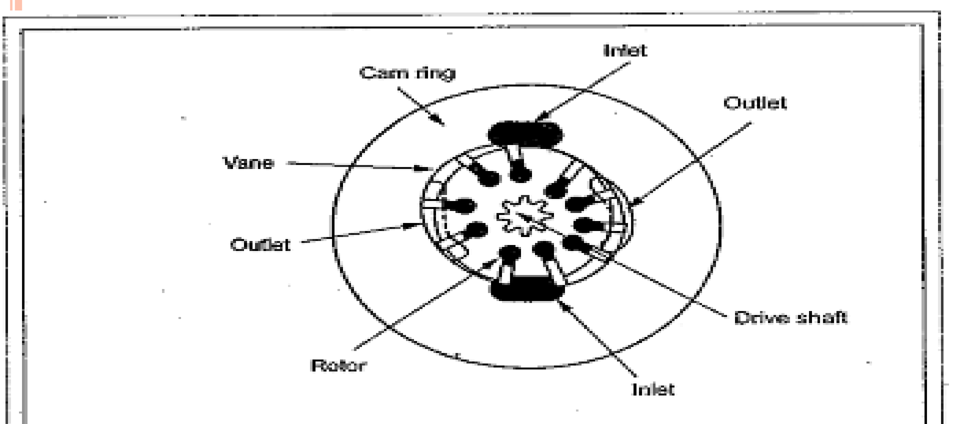
1. Continuous rotary hydraulic motors, and

   (*i*) Gear motors, (*ii*) Vane motors, and (*iii*) Piston motors.

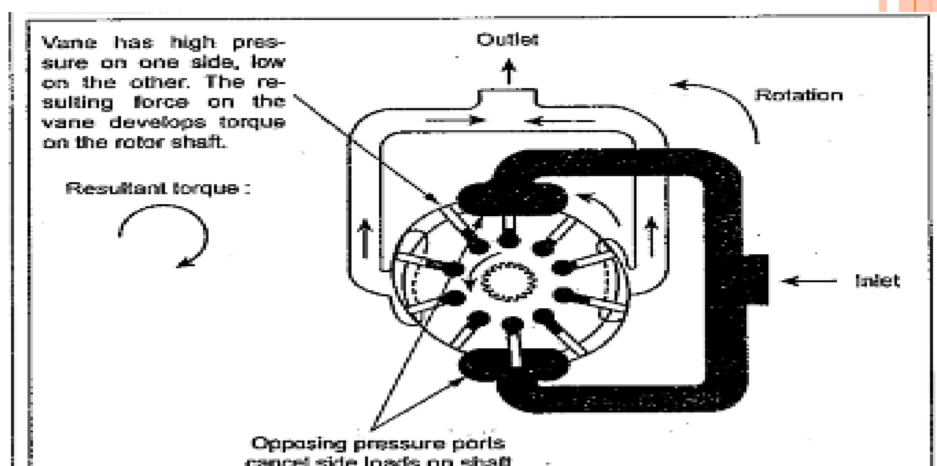
2. Limited rotation hydraulic motors†

   (*i*) Vane type, and (*ii*) Piston type.


4. These teeth does not affect the torque as the pressure between these teeth pushes them in both ways.
1. Two teeth faces with high pressures on one side, and low pressure on the other produce a resultant torque:
2. One tooth face with high pressure on one side, and low pressure on the other produce a resultant torque: (which tend to opposite rotation)
∴ Net torque and rotation is:
(1) – (2) – (3) =
Inlet
(High pressure)
Outlet
(Low pressure)
3. Two teeth faces have only low outlet pressure produce a low torque opposing rotatoin as:


Inlet
Cam ring
Outlet
Vane
Outlet
Drive shaft
Rotor
Inlet

(a)


Vane has high pressure on one side, low on the other. The resulting force on the vane develops torque on the rotor shaft.
Outlet
Rotation
Resultant torque :
Inlet
Opposing pressure ports cancel side loads on shaft

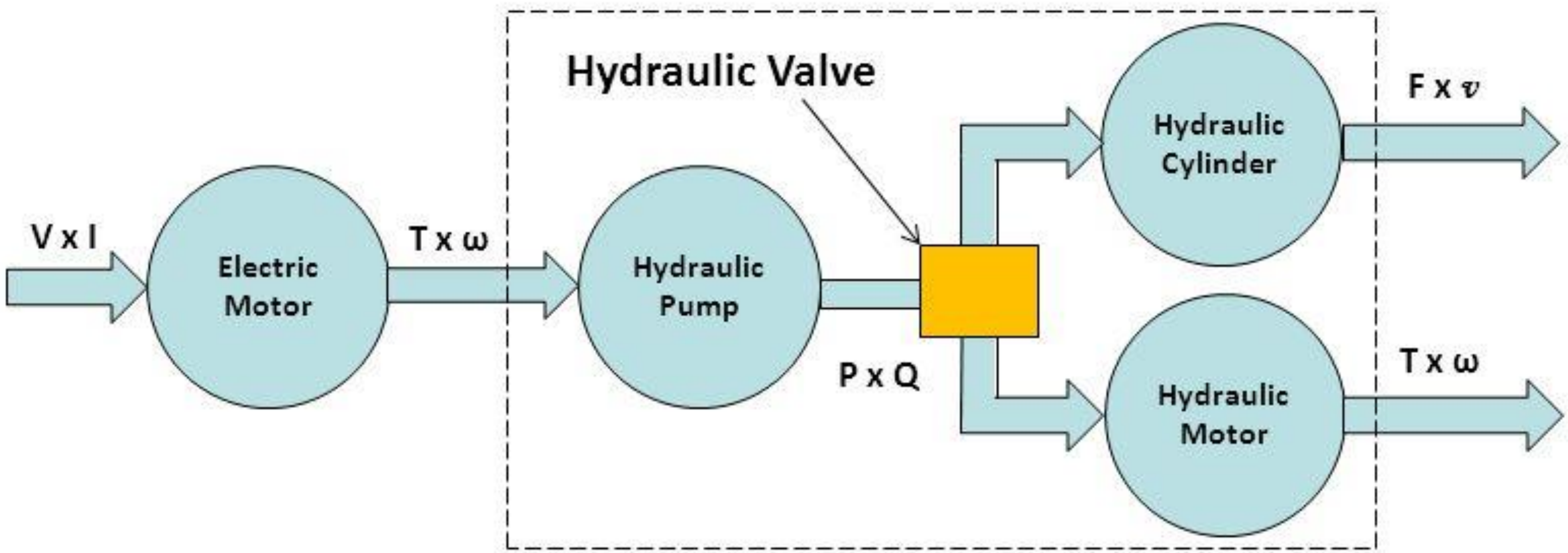
(b)

Unit-III

Design of Hydraulic Circuits

Introduction

- Hydraulic valves are those elements that control the direction and amount of fluid power in a circuit. They do this by controlling the pressure and the flow rate in various sections of the circuit.



Types of control valves

1. Direction Control Valves
2. Pressure Control Valves
3. Flow Control Valves

I. Direction control valves

- **Directional control valves (DCV)** are one of the most fundamental parts in hydraulic machinery as well as pneumatic machinery.
- They allow fluid flow into different paths from one or more sources. They usually consist of a spool inside a cylinder which is mechanically or electrically controlled.

✓ In other words, *directional control valves (DCVs) regulate the direction in which the fluid flows in a hydraulic circuit.*

Classification of Directional control valves

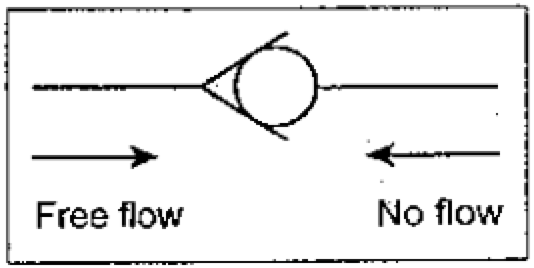
1. According to type of construction :
   - Poppet valves
   - Spool valves
2. According to number of working ports :
   - Two- way valves
   - Three – way valves
   - Four- way valves.
3. According to number of Switching position:
   - Two – position
   - Three – position
4. According to Actuating mechanism: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

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

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

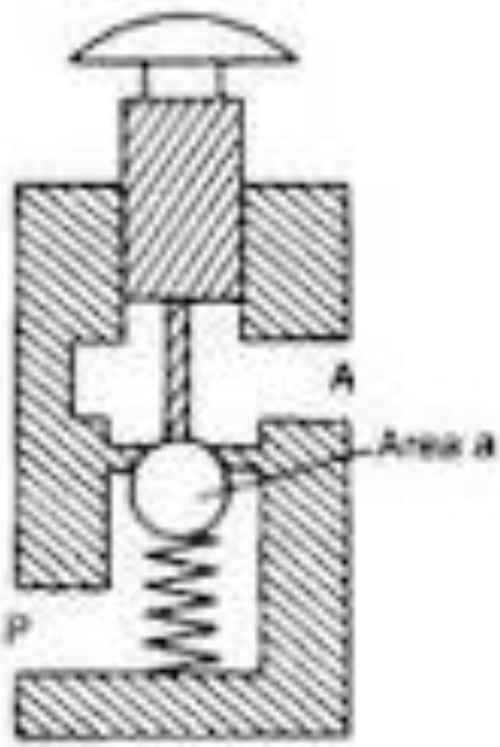
1. Check Valve

- ✓ Check valves are the most commonly used and the simplest type of directional control valves.
- ✓ The check valve is a ***two-way valve*** because it contains two ports. Also *a check valve is analogous to a diode in electric circuits.*
- ✓ ***Functions :*** The check valves are used :
  - (*i*) to allow free flow in only one direction, and
  - (*ii*) to prevent any flow in the other direction.
- ✓ Since check valves block the reverse flow of the fluid, they are also known as ***non-return valves.***
- ✓ The symbolic representation of a check valve, shown in Fig.7.4, illustrates its function clearly.

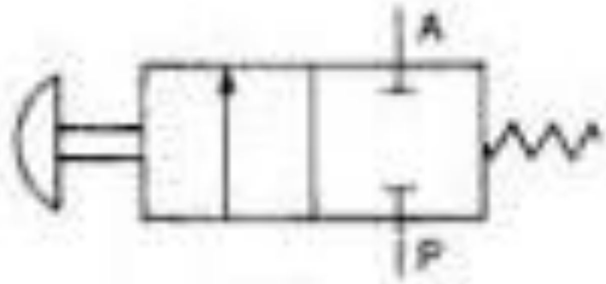


1. Poppet-type check valves, and
2. Pilot-operated type check valves.

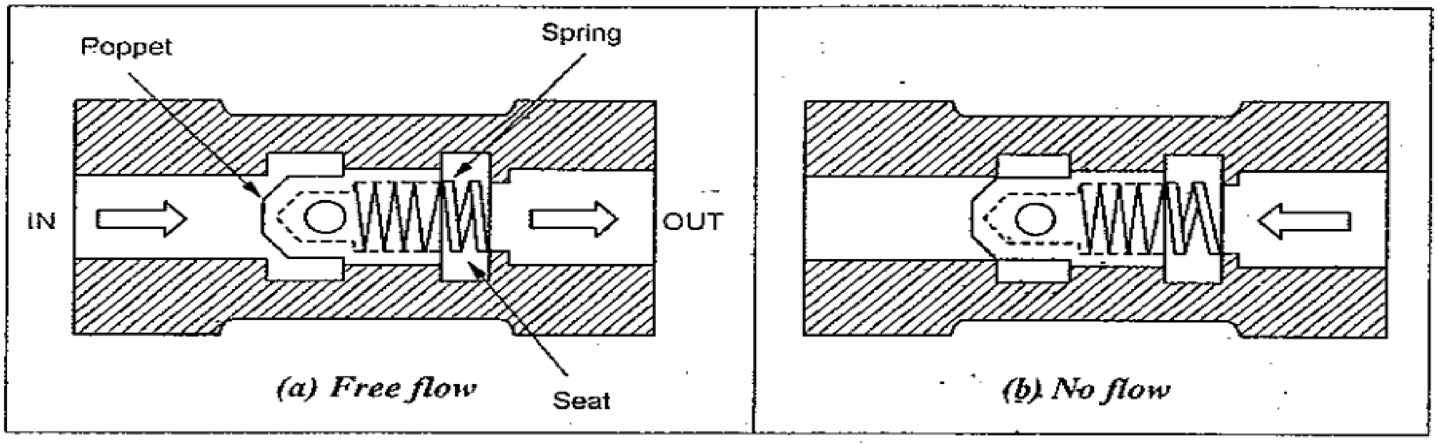
POPPET TYPE CHECK VALVES



(a) Construction

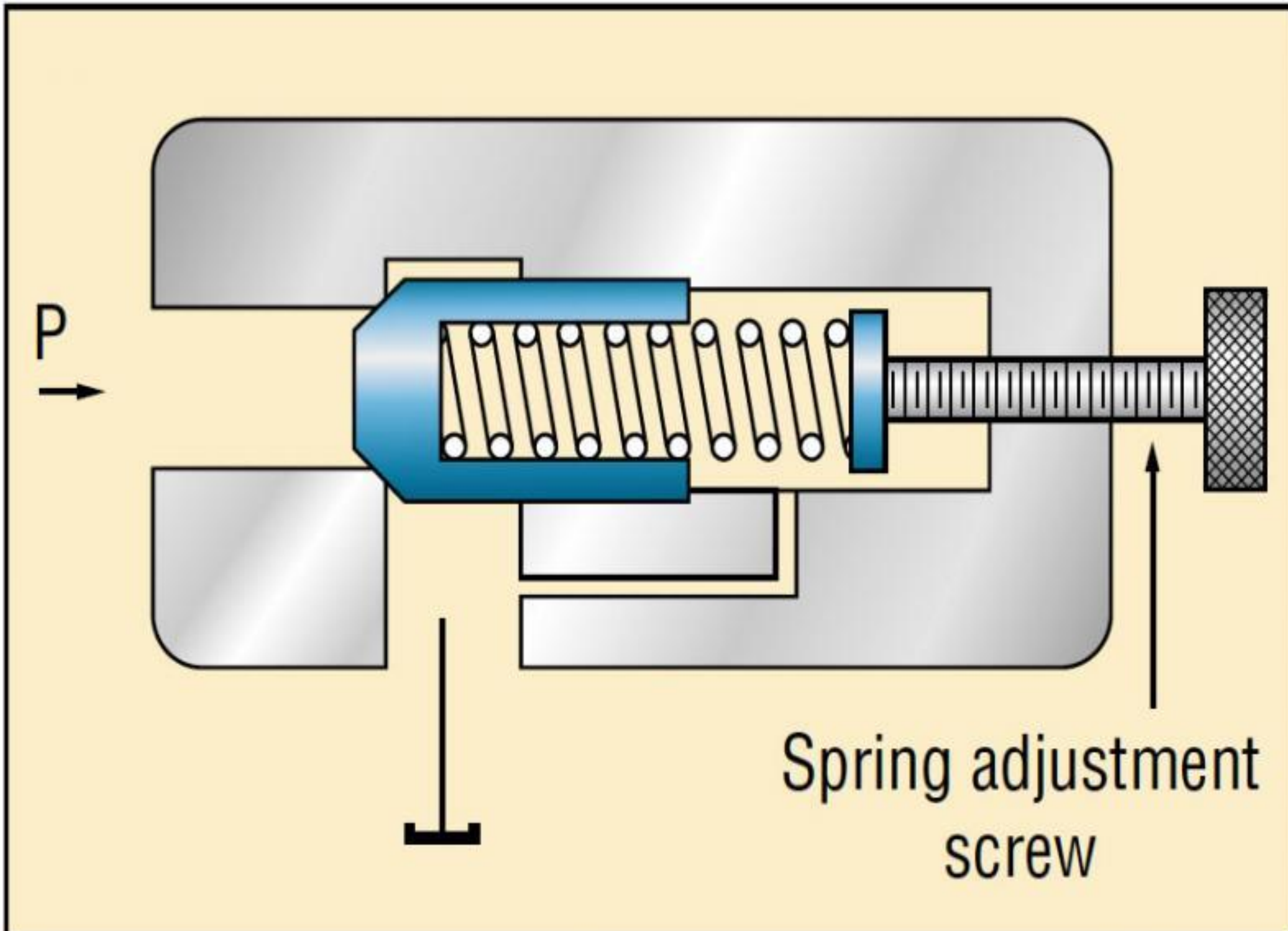


(b) Symbol



(a) Free flow

(b) No flow



P
Spring adjustment screw

PILOT-OPERATED CHECK VALVES

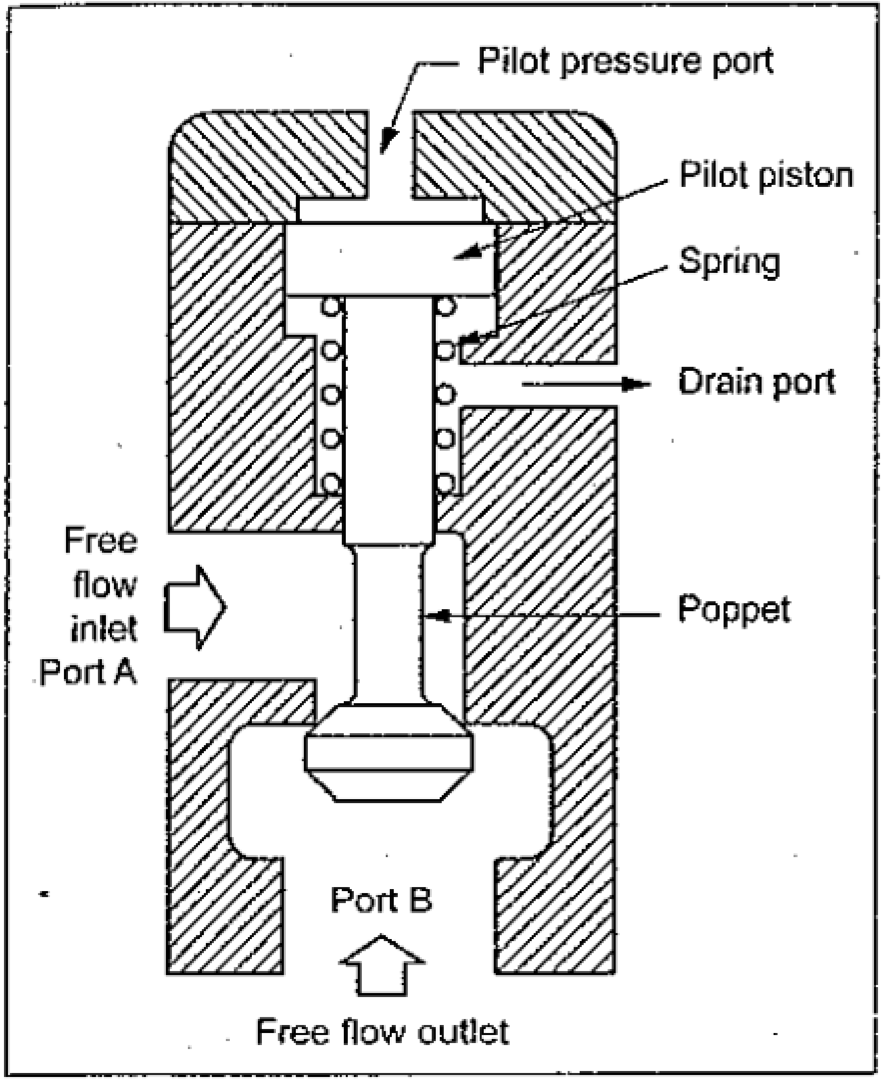


Fig. 7.6. Pilot-operated check valve

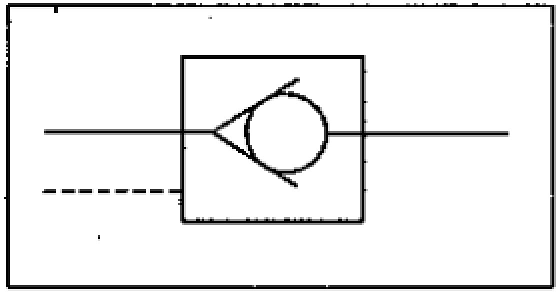


Fig. 7.7. Symbolic representation

2. Position Valves

- ✓ *The function of the position valve is to control the introduction of fluid to the lines of the system.* When the valve is operated, the liquid lines within it are shifted.
- ✓ The position valves are usually described by the following relation :

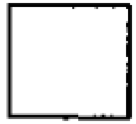
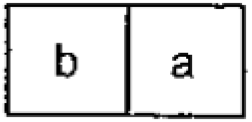
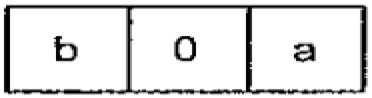
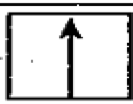
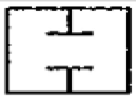
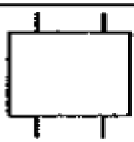
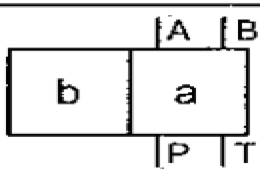
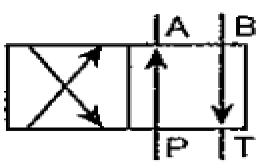
(Number of ports/Number of positions) valve.

For example, a 4/2 valve has 4 ports and 2 positions.

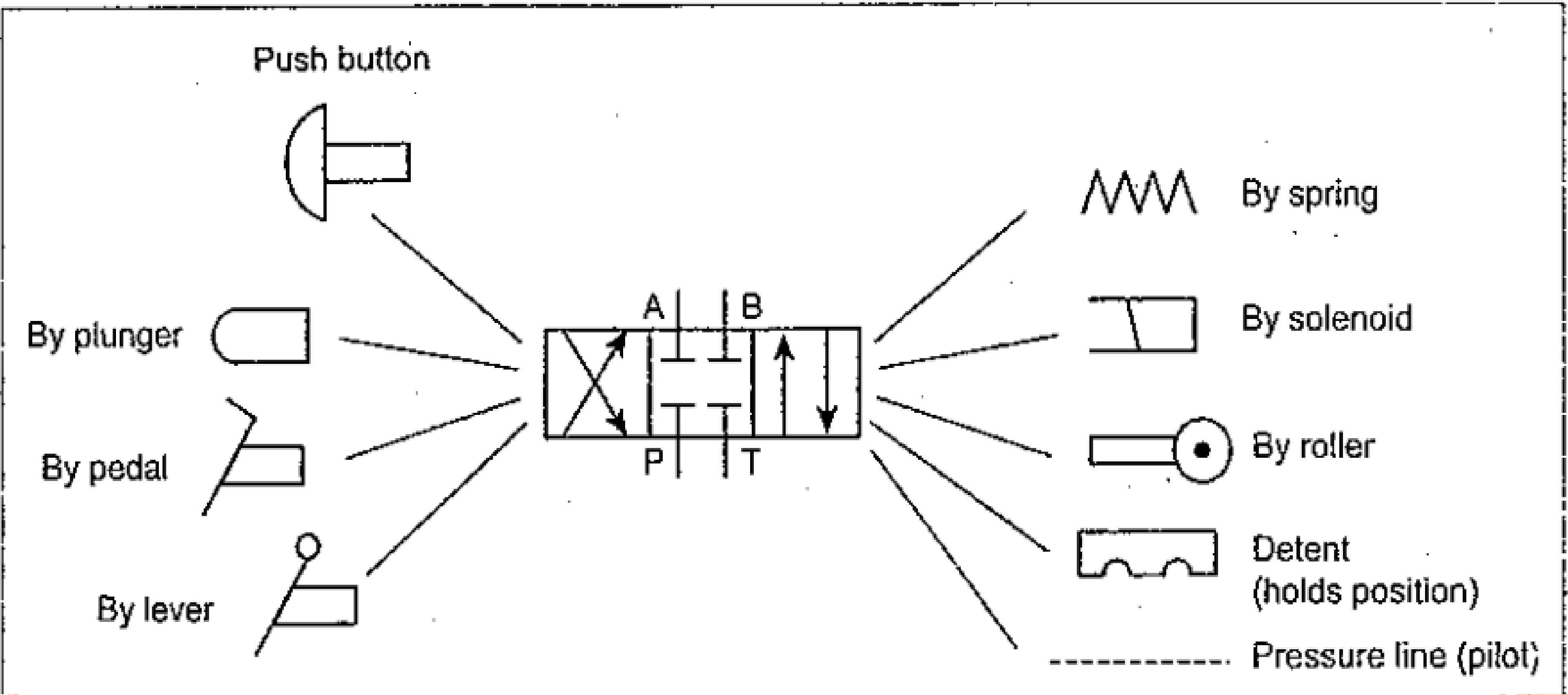
- ✓ The ports of a directional control valve are designated by letters, as listed in Table 7.1.

Table 7.1. Ports' designations

Ports	Designation
Working lines	A, B, C, and so on.
Pressure (power) supply	P
Return/Exhaust lines	R, S, T and so on. (Normally T for hydraulic systems, R and S for pneumatic systems.)
Control (pilot) lines	Z, Y, X, and so on.

	Valve symbol	Description
Valve position		A valve position is represented by a square.
Two position valve		A number of squares is equal to the number of distinct positions that the valve can take up. Therefore the figure shows the two position valve.
Three position valve.		Three adjacent squares indicate the three position valve.
Flow path		Inside a square, the line indicates the flow and the arrow the direction of flow.
Flow shut off		Cut-offs of fluid flow are shown by short transverse lines inside the square.
Initial convections		The ports of a valve are added on the outside of the square box. The connections to inlet and outlet ports are drawn only to a initial (or neutral) position.
4/2 valve		Figure shows the 4 ports (A, B, P and T) and 2 positions (*a* and *b*) valve.
4/2 valve		In position '*a*', the fluid is delivered from port P to port A and returned from port B to port T. In position '*b*', flow is reversed, *i.e.*, the fluid is delivered from port P to port B and returned from port A to port T. [*Note :* Here ports are drawn only to the initial position. For the other position, readers should mentally identify the ports.]

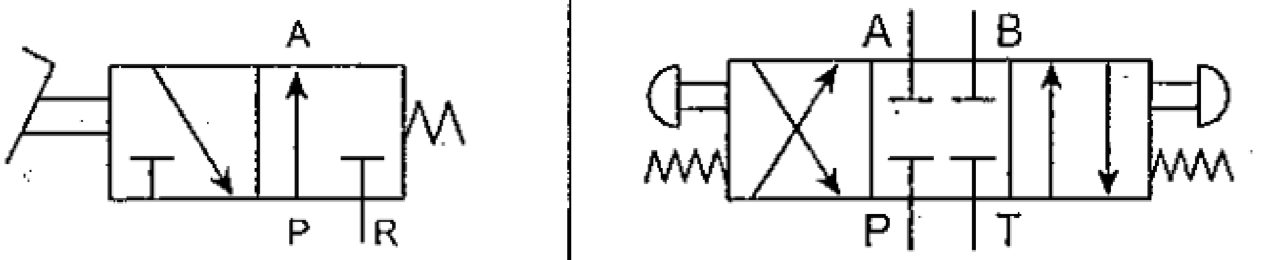
Valve Actuation Symbols



Complete Graphic Symbols

Fig.7.9 illustrates how these various symbols can be combined to describe a complete valve operation. Fig.7.9(*a*) represents a pedal actuated, spring return 3/2 valve.

Fig.7.9(*b*) represents push-button operated, spring return, 4/3 valve.



(a) 3/2 valve, pedal actuated, spring return to centre

(b) 4/3 valve, push button operated, spring return to centre

Classification of Position Valve

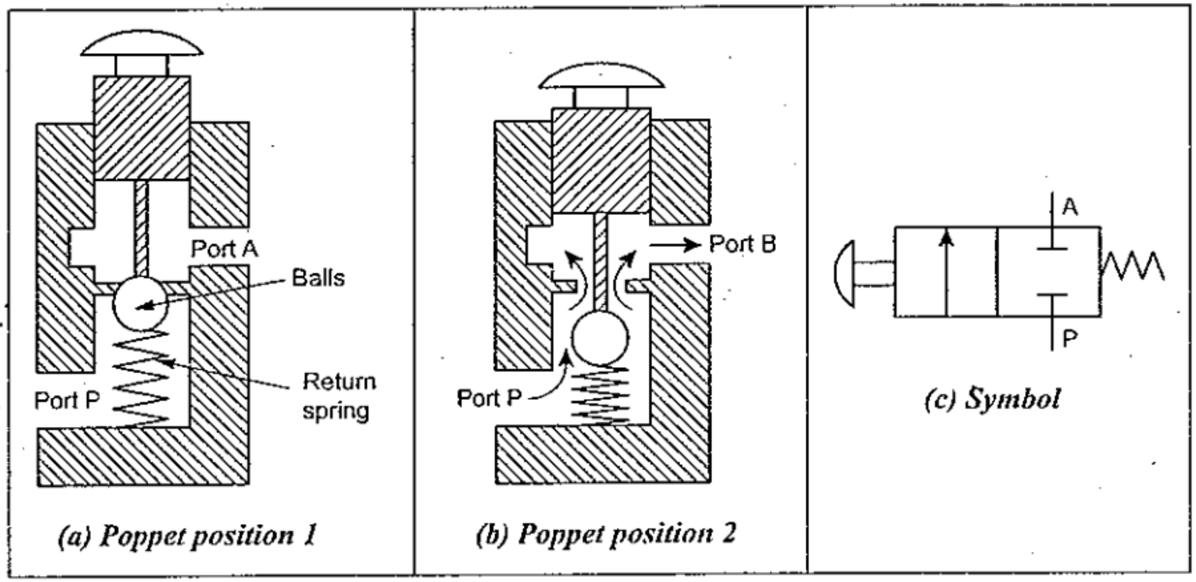
(*i*) Two way, two position valves (2/2 valves).

(*ii*) Three way, two position valves (3/2 valves).

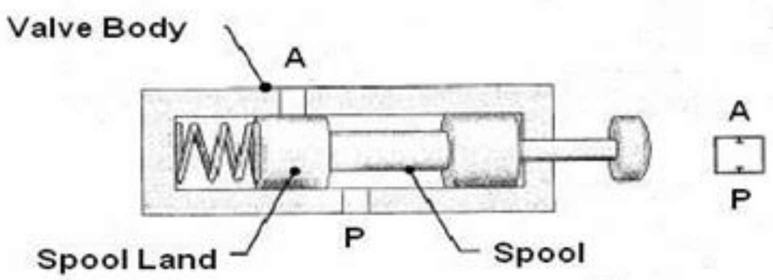
(*iii*) Four way, two position valves (4/2 valves),

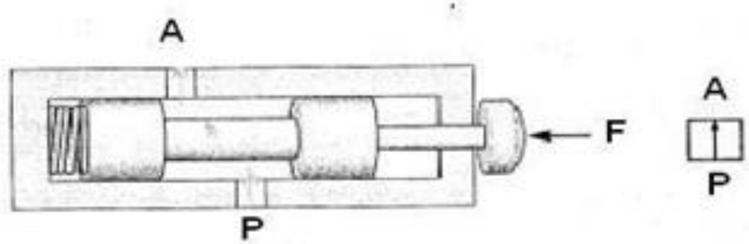
(*iv*) Four way, three position valves (4/3 valves), and so on.

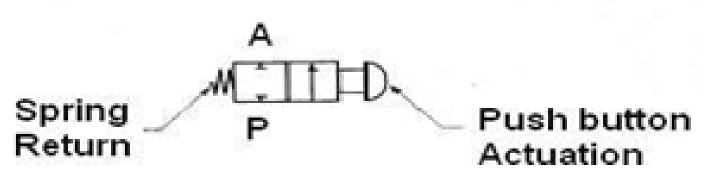
2/2 Directional Control Valve



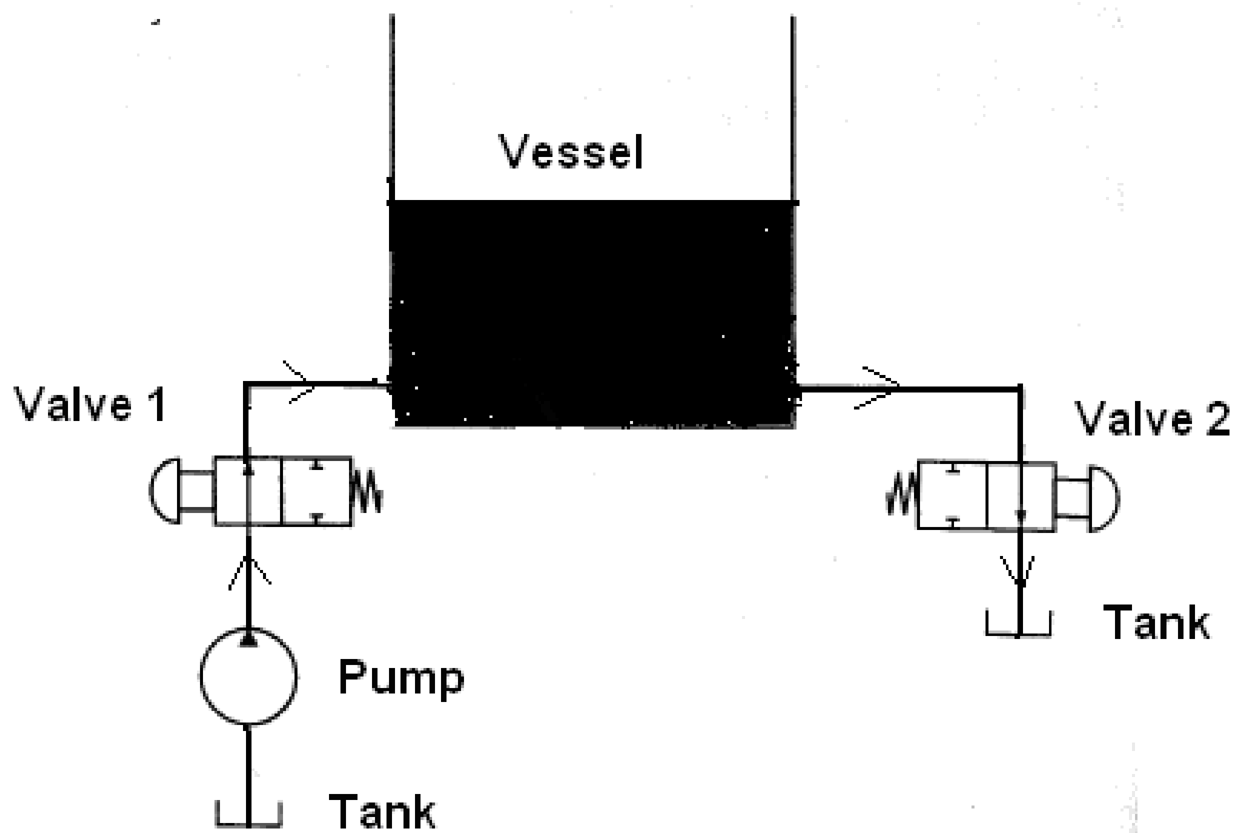
(a) Poppet position 1 (b) Poppet position 2 (c) Symbol



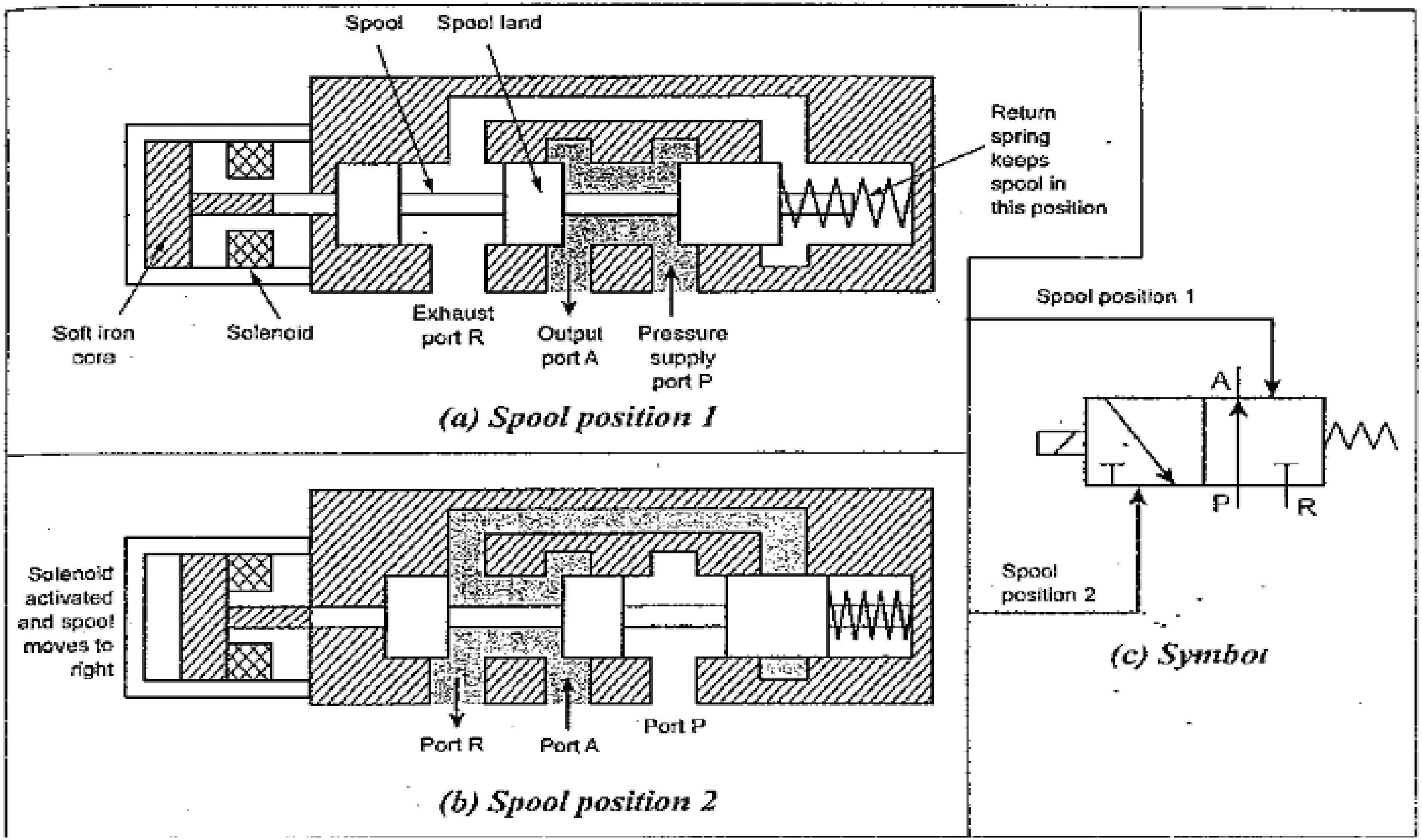




Application of Two way DCV valves



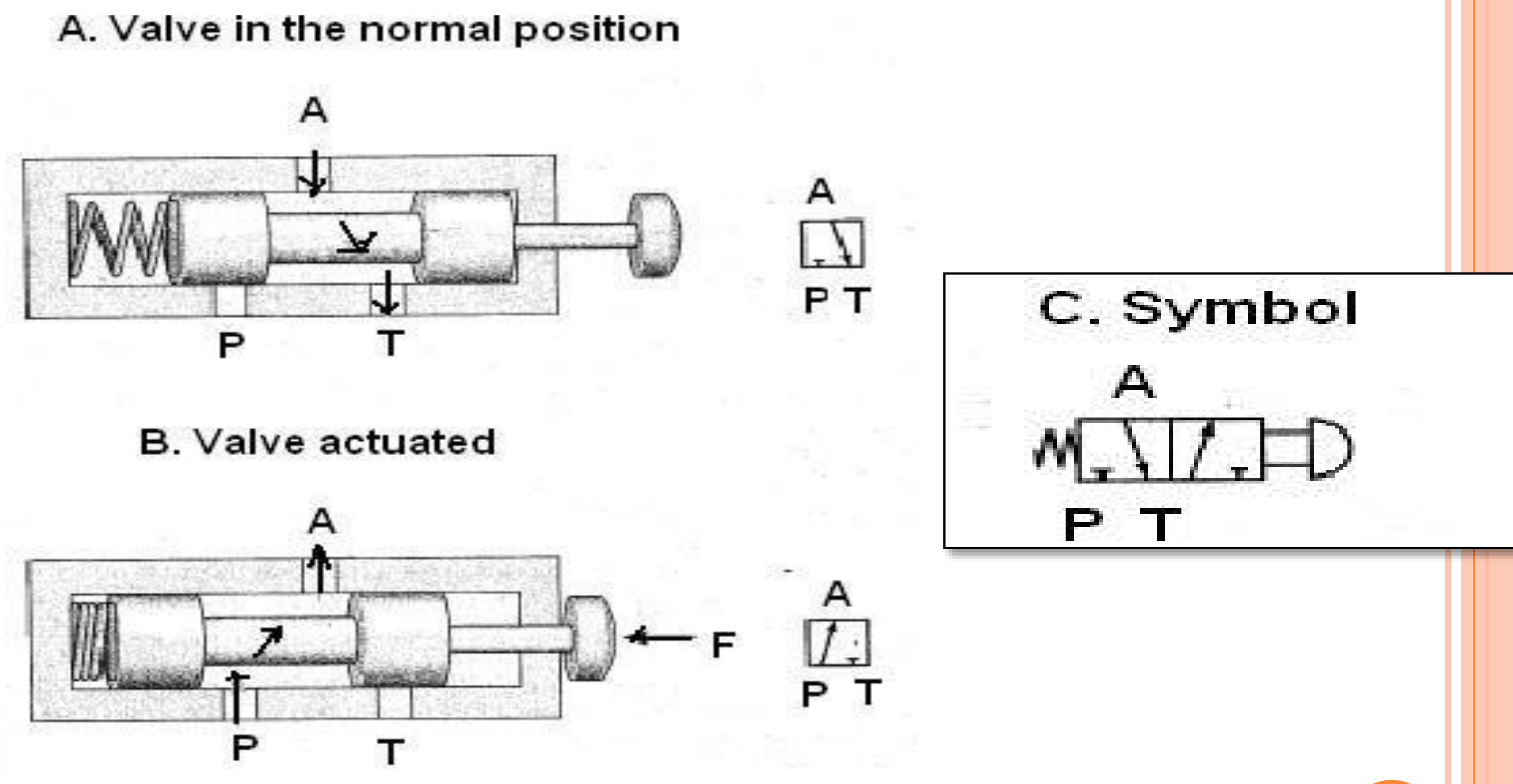
3/2 Directional Control Valve DCV



Spool position 1 : In the original or neutral position of the spool, (Fig.7.11(*a*)), the pressurized fluid flows from port P to port A to move the actuator, the exhaust port (R) remaining closed.

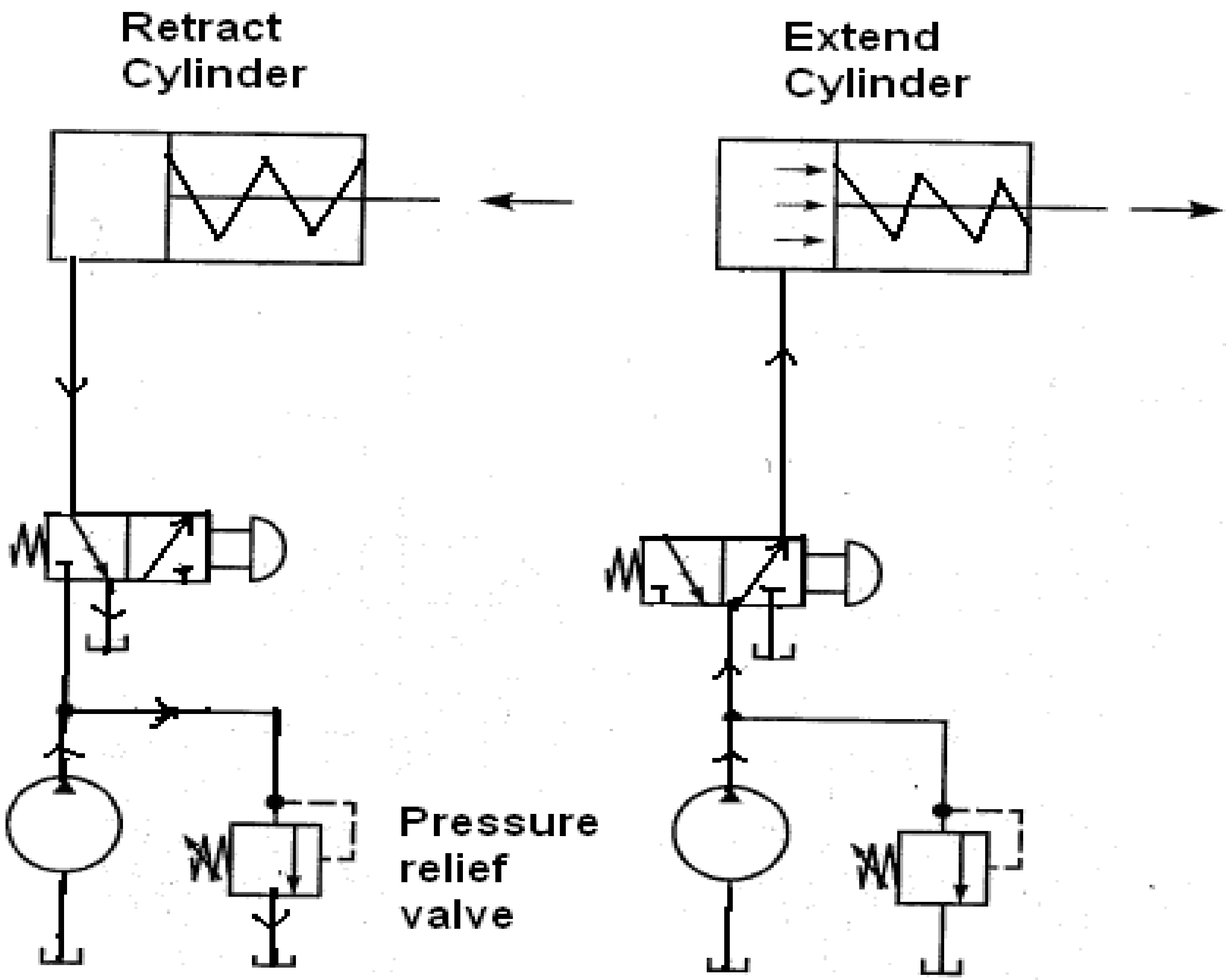
Spool position 2 : When the solenoid is activated (Fig.7.11(*b*)), the spool moves to the extreme left. In the extreme spool position, the fluid from port P gets closed and hence the fluid is permitted to flow from port A to port R.

3/2 Directional Control Valve DCV

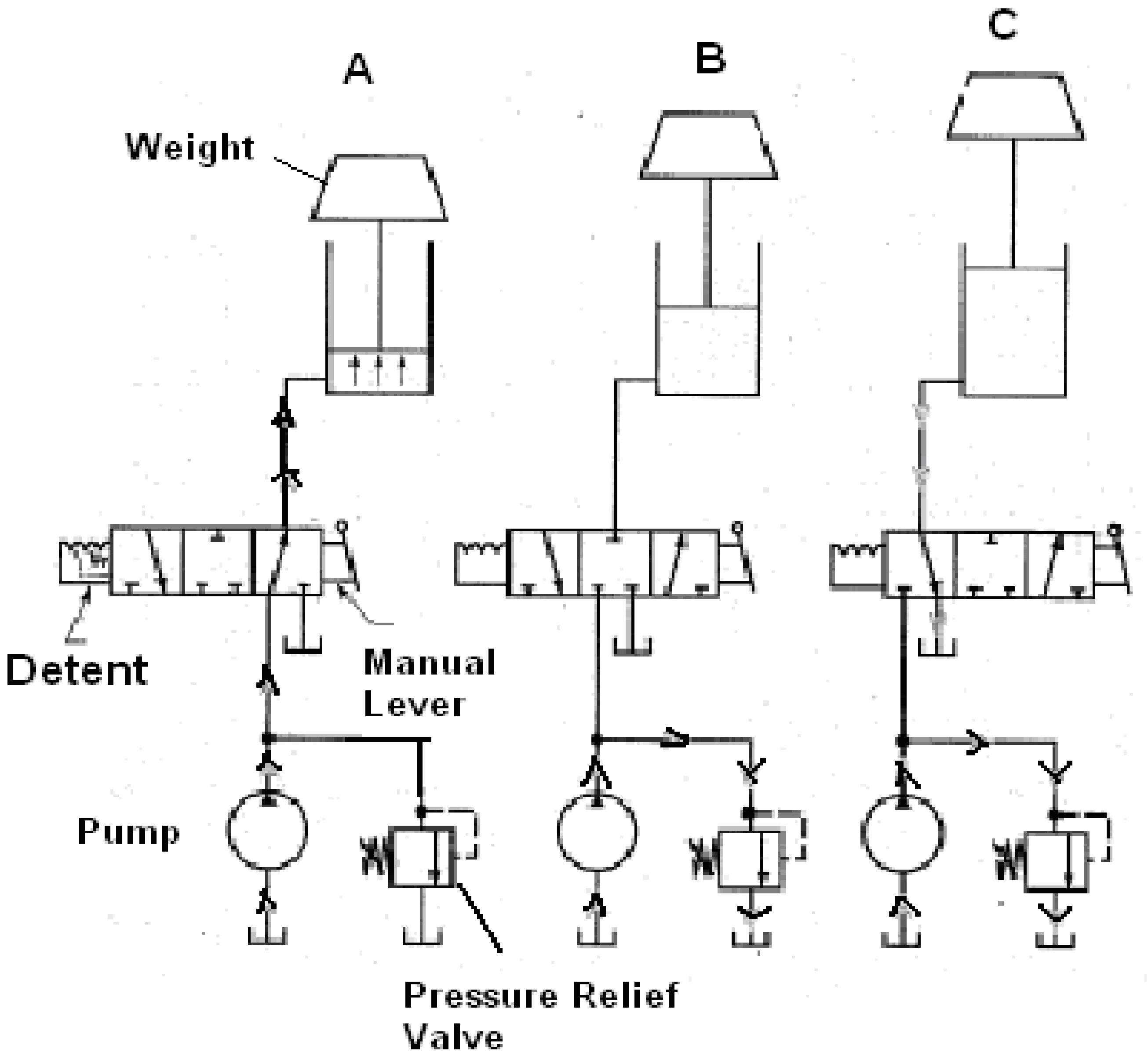


https://www.youtube.com/watch?v=AhjyPhohbnU

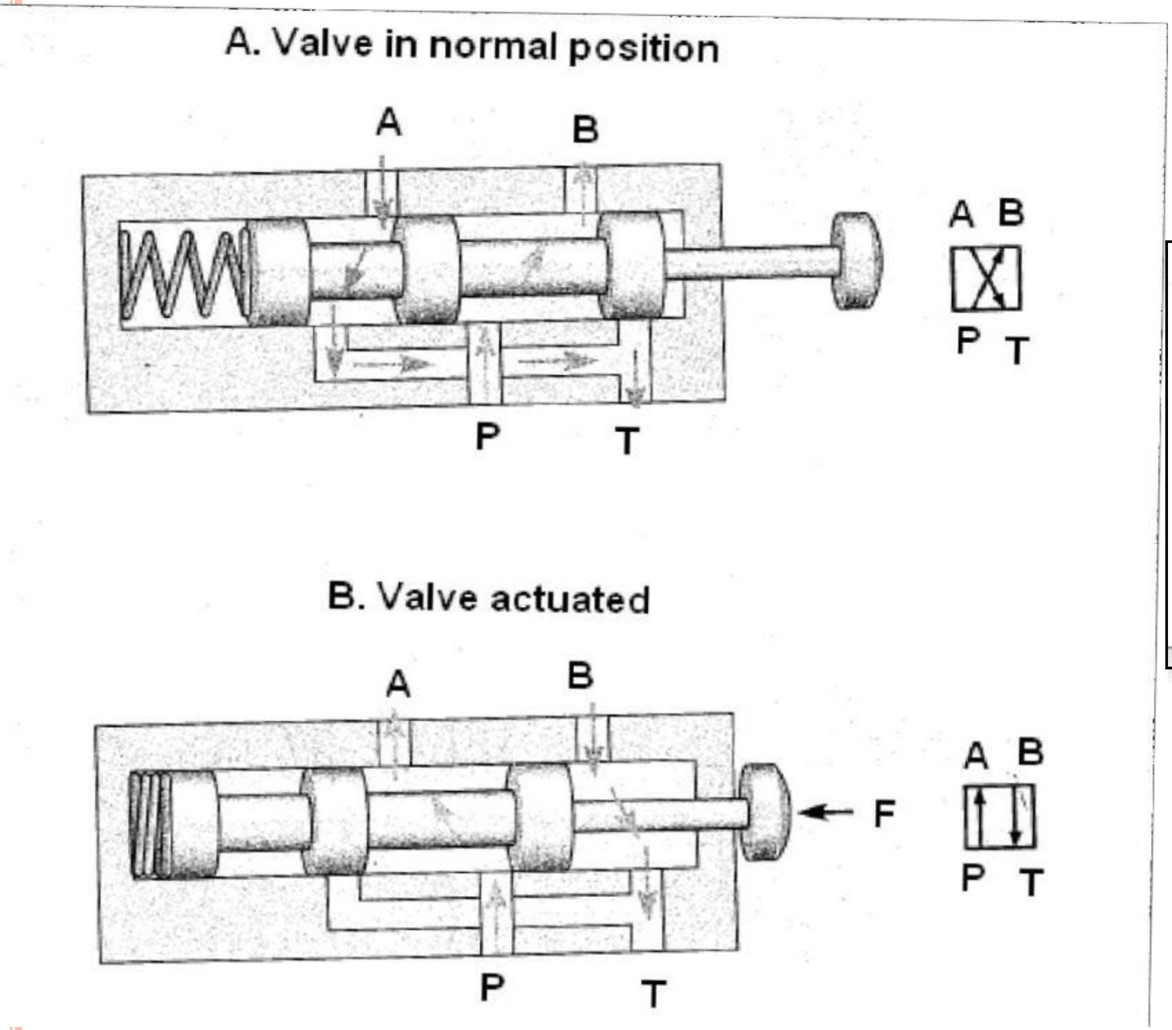
Application of 3/2 DCV

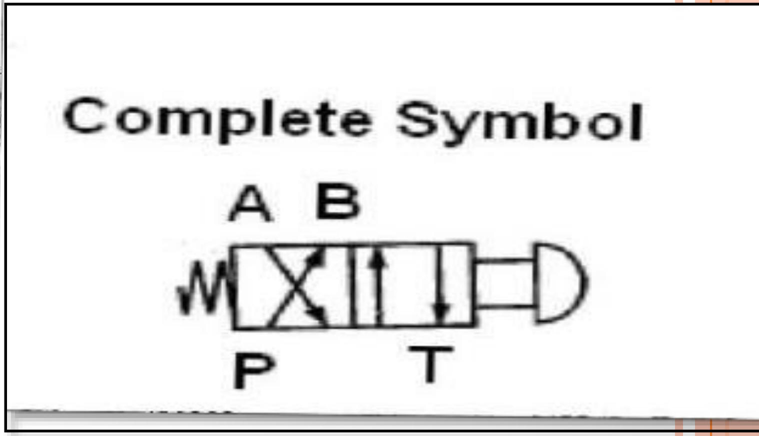


Application of 3 way 3 position DCV

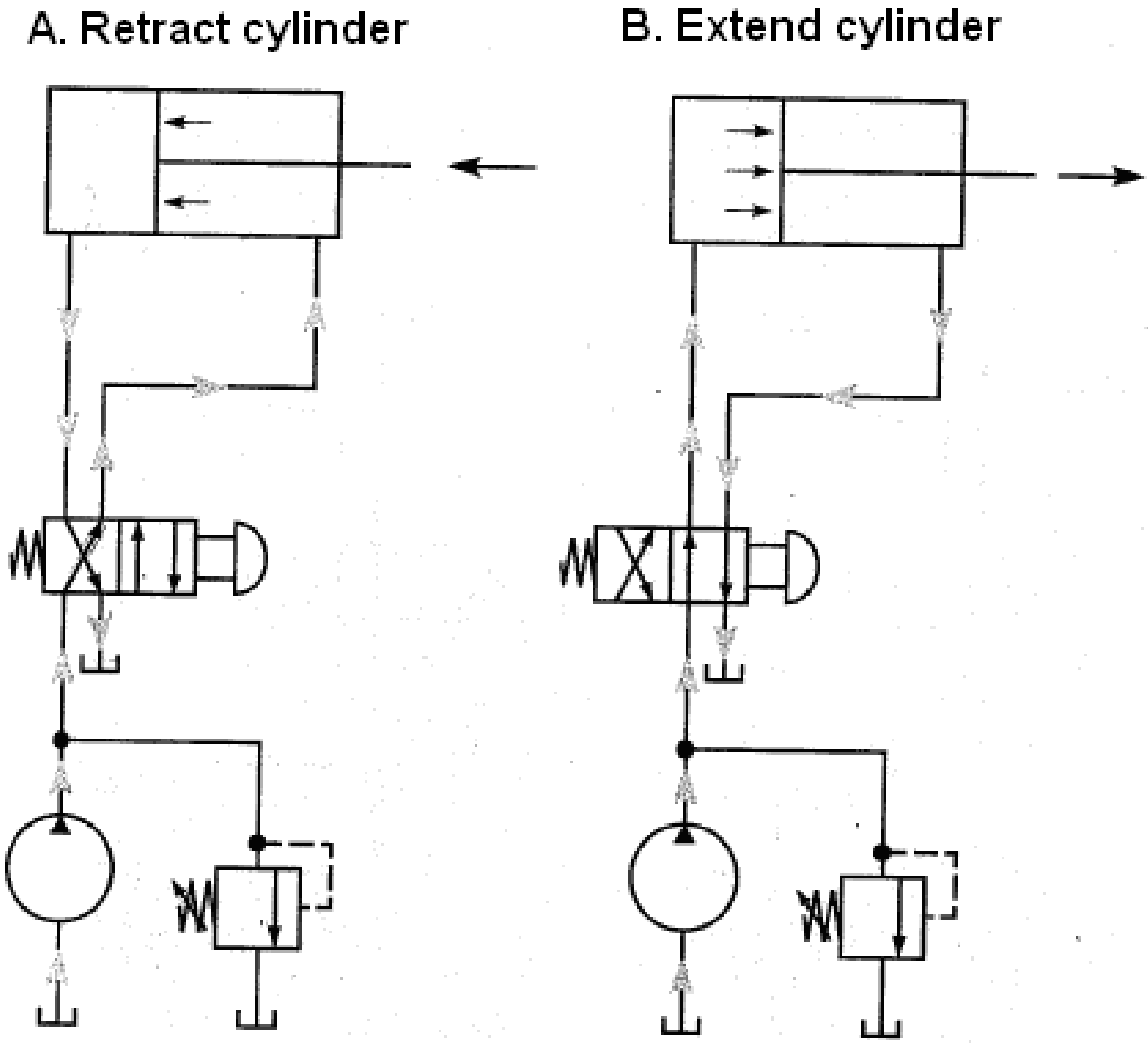


FOUR WAY DIRECTIONAL CONTROL VALVES (4/2 DCV)





APPLICATION OF 4/2 DCV



3.Shuttle valve

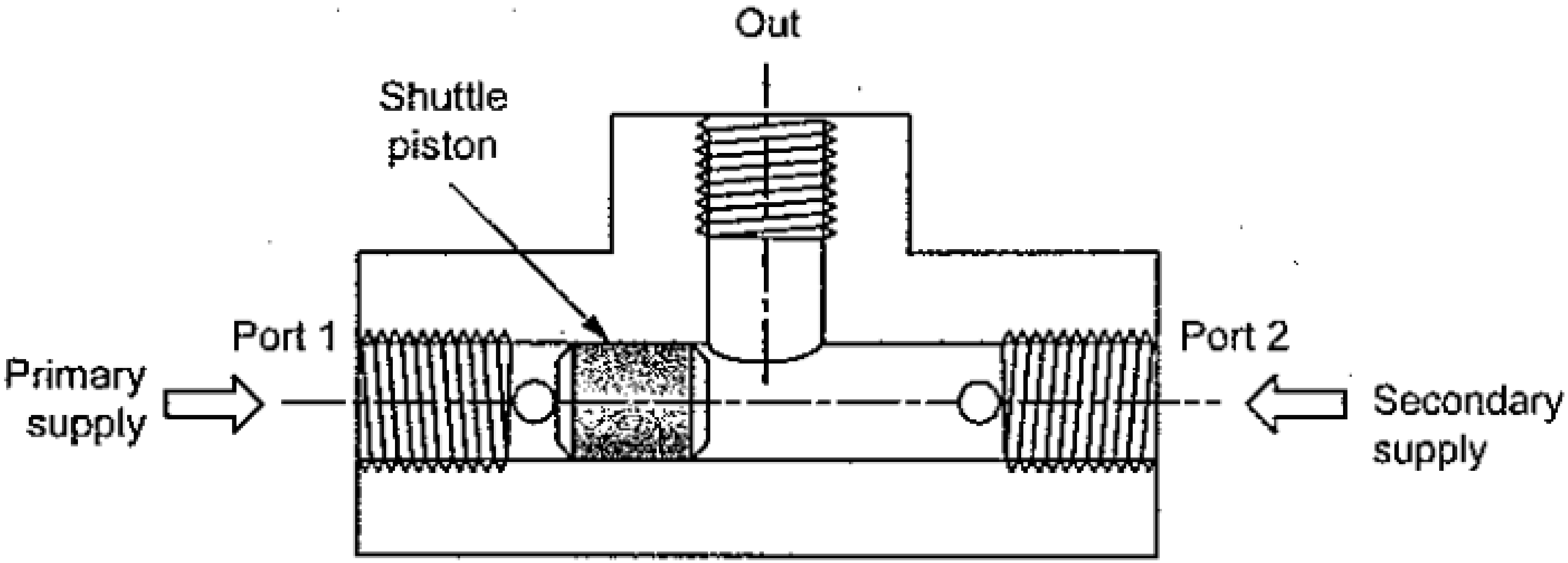
- These valves allow two alternate flow sources to be connected to one branch circuit. They have two inlets (P1 and P2) and one outlet (A).

✓ Shuttle valve is also a typical directional control valve.

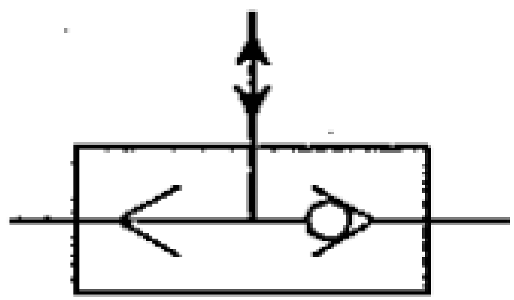
✓ *Shuttle valves, also known as* ***double check valves****, are used when control is required from more than one power source.*

✓ In other words, a shuttle valve allows pressure in a line to be obtained from alternative sources.

✓ Shuttle valve is generally used to shift the fluid flow from the secondary backup pump (source), when the main pump (source) becomes inoperate.



(a) Operation



(b) Graphic symbol

II. PRESSURE CONTROL VALVES

- ✓ As the name suggests, *pressure control valves are the devices used to control the fluid pressure in a system.*

- Functions

(*i*) To limit the maximum pressure in various circuit components as a safety measure.

(*ii*) To maintain the desired pressure levels in various parts of the circuits.

(*iii*) To unload system pressure, *i.e.*, to change the direction of all or part of the flow when the pressure at a certain point reaches a specified level.

(*iv*) To assist sequential operation of actuators in a circuit with pressure control.

Sl.No.	Type	Function/Description
1.	Pressure limiting valve (relief valve)	Relief valve limits the maximum pressure that can be applied to the part of the system to which it is connected.
2.	Pressure reducing valve (pressure-regulator valve)	Pressure reducing valve maintains a prescribed reduced pressure at its outlet regardless of the valve inlet pressure.
3.	Sequence valve	Sequence valve directs flow to more than one portion of a fluid circuit in sequence.
4.	Counterbalance valve (Back-pressure valve)	Counterbalance valve permits free flow in one direction and restricted flow in the opposite direction.
5.	Unloading valve	Unloading valve allows pressure to build up to an adjustable setting, then bypasses the flow as long as a remote source maintains the preset pressure on the pilot port.
6.	Pressure switch	Pressure switch is used when a pressure-actuated electric signal is required for system control.
7.	Hydraulic fuse	✓ Hydraulic fuse employs a frangible diaphragm, which establishes the maximum pressure in a hydraulic circuit by rupturing at a preset pressure valve. ✓ Hydraulic fuse, analogous to an electric fuse, is used to prevent the system pressure from exceeding beyond the allowable limit in order to protect the system components from damage.

1. Pressure Limiting Valve (Relief valve)

- **What is a Pressure limit valve?**

✓ The pressure-limiting valve, also known as the ***relief valve***, is the protector of the hydraulic circuit.

✓ A relief valve limits the maximum pressure that can be applied to the part of the system to which it is connected.

✓ In other words, *a relief valve protects a system from excessive fluid pressure over and above the design pressure limit.*

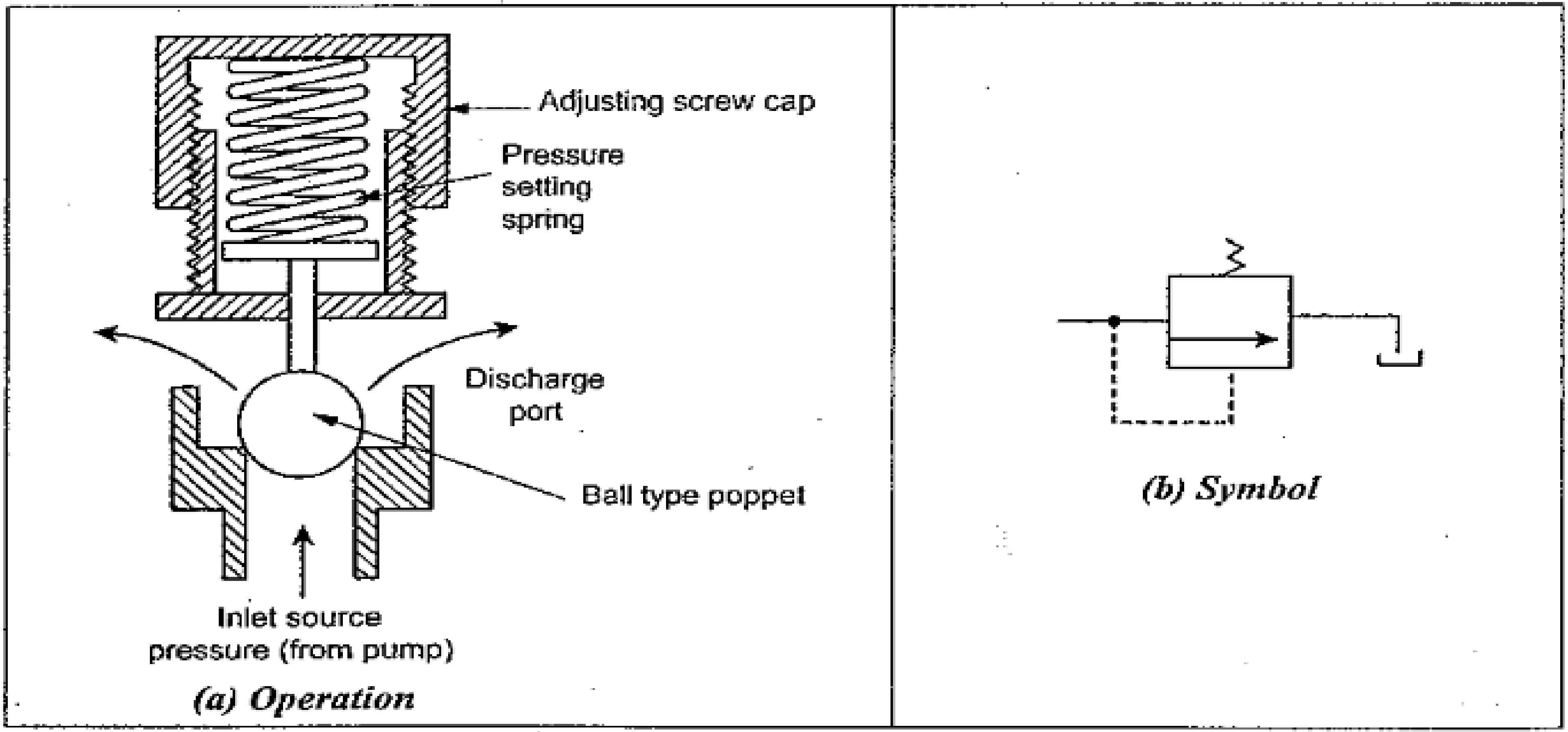
✓ Normally the pressure relief valve is located in between the pump and the actuator. Thus the relief valve protects the pump, the electric motor, and also other components of the circuit.

- **Types of Relief valve**

1. Direct-acting or simple pressure relief valve, and
2. Pilot-operated or compound pressure relief valve.

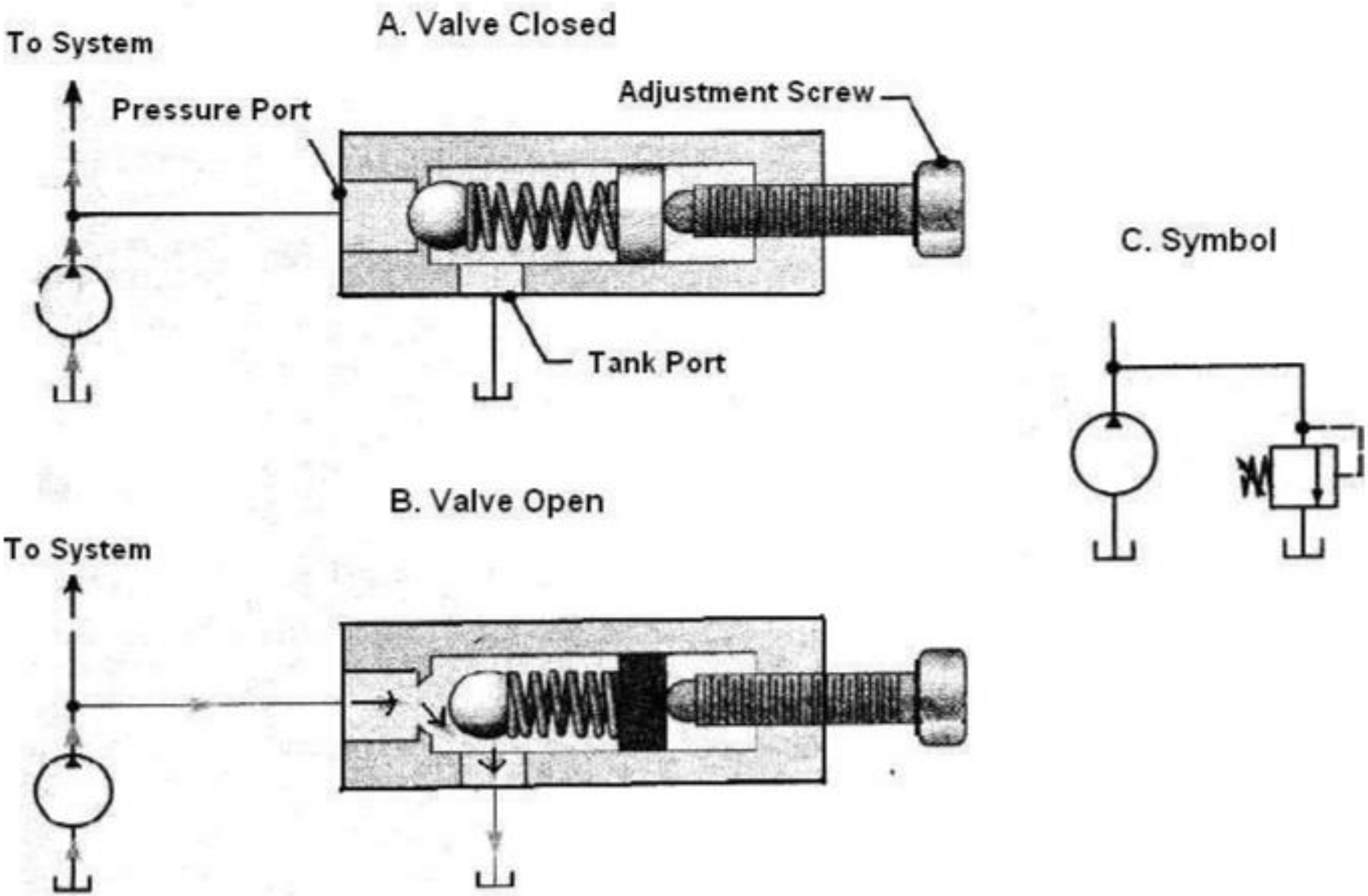
https://www.youtube.com/watch?v=vfz_CM0ygs4

Direct acting (Simple) pressure relief valve

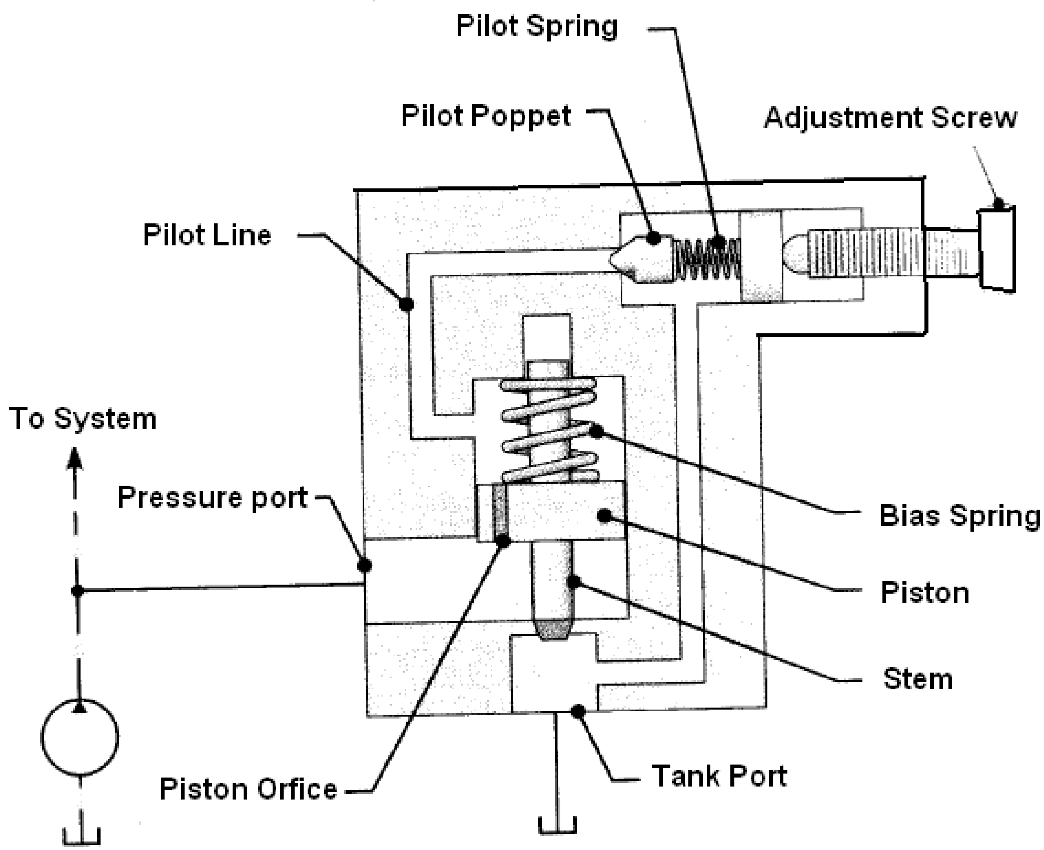


When the inlet pressure overcomes the force exerted by the spring, the valve opens and vents to the atmosphere or back to the sump. Thus the relief valve protects the other elements in the system from excessive pressure by diverting the excess fluid to the sump or atmosphere when the system pressure tends to exceed the preset level.

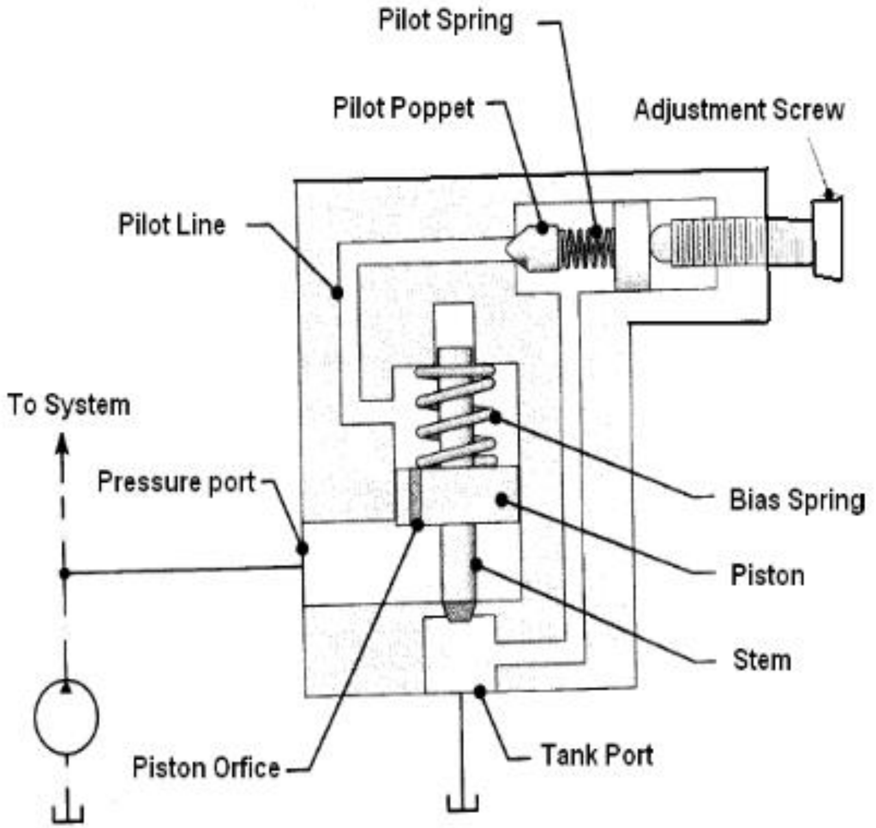
The direct-acting type of relief valves have a ball, poppet or a sliding spool working against a spring. As the inlet pressure decreases, the valve closes again. The adjusting screw cap is used to adjust the pressure limit and to vary the spring force.


A. Valve Closed
To System
Pressure Port
Adjustment Screw
Tank Port
C. Symbol
B. Valve Open
To System

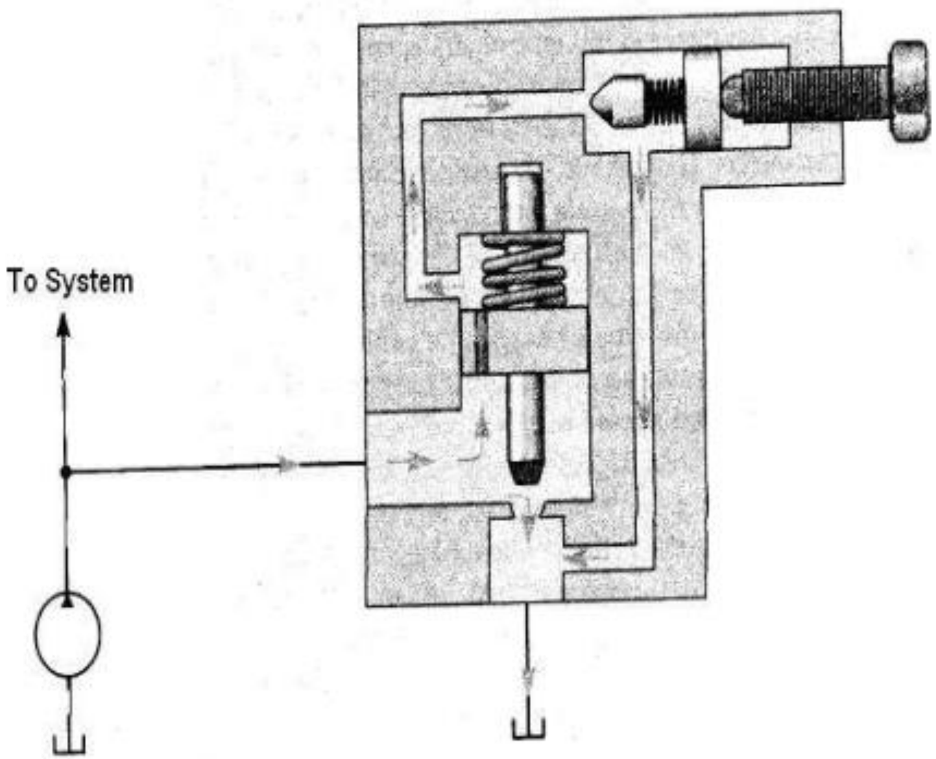
Compound (Pilot-Operated) Pressure Relief valve



When the system pressure exceeds the setting pressure of the main poppet, the poppet is pushed from its seat towards left. This forces the pressurised fluid on the left side to escape through the centrally drilled drain hole of the main poppet. This limits the pressure on the control chamber side. Due to the restricted flow through the orifice, the fluid cannot enter into the control chamber as quickly as the fluid leaves through the drain hole. Because of this, the pressure on the right side exceeds that on the left and the main poppet moves to the left. Thus it permits the fluid flow directly to the reservoir tank from the inlet port. When the pressure falls below the setting pressure, the main poppet retracts back to its original position again.



A- Pilot operated pressure relief valve -Closed

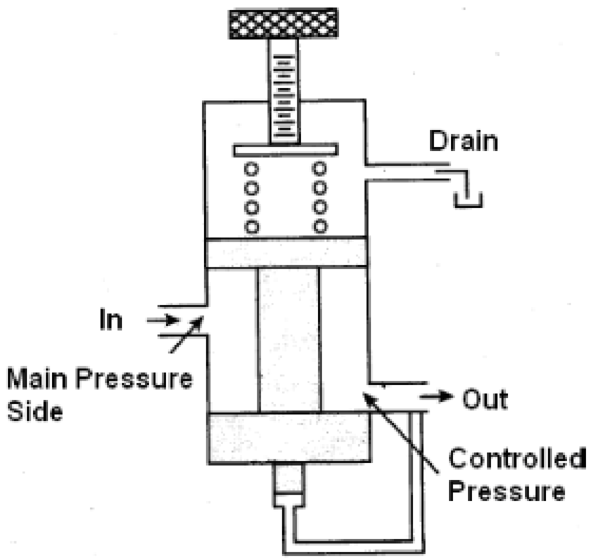


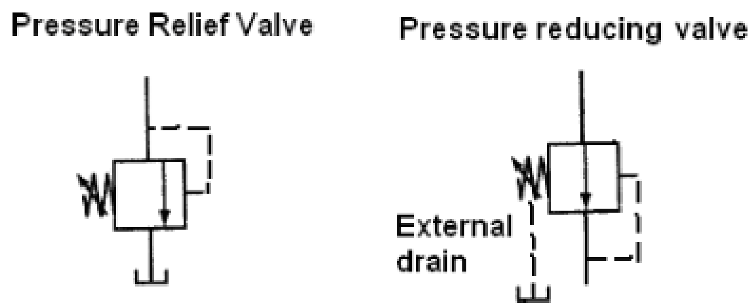
B- Pilot operated pressure relief valve- Open

Pressure Relief Valves: Direct Acting and Pilot Operated - Working

https://www.youtube.com/watch?v=vfz_CM0ygs4

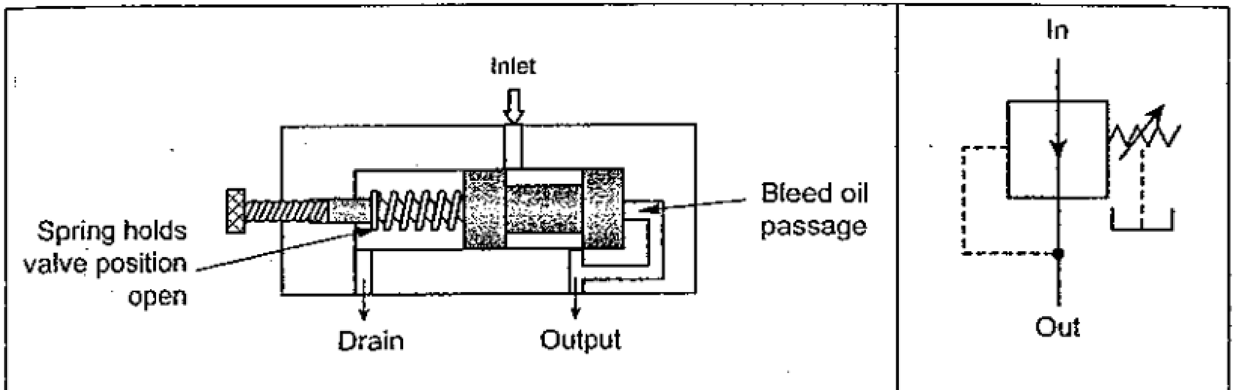
Pressure reducing valve (Pressure Regulator)





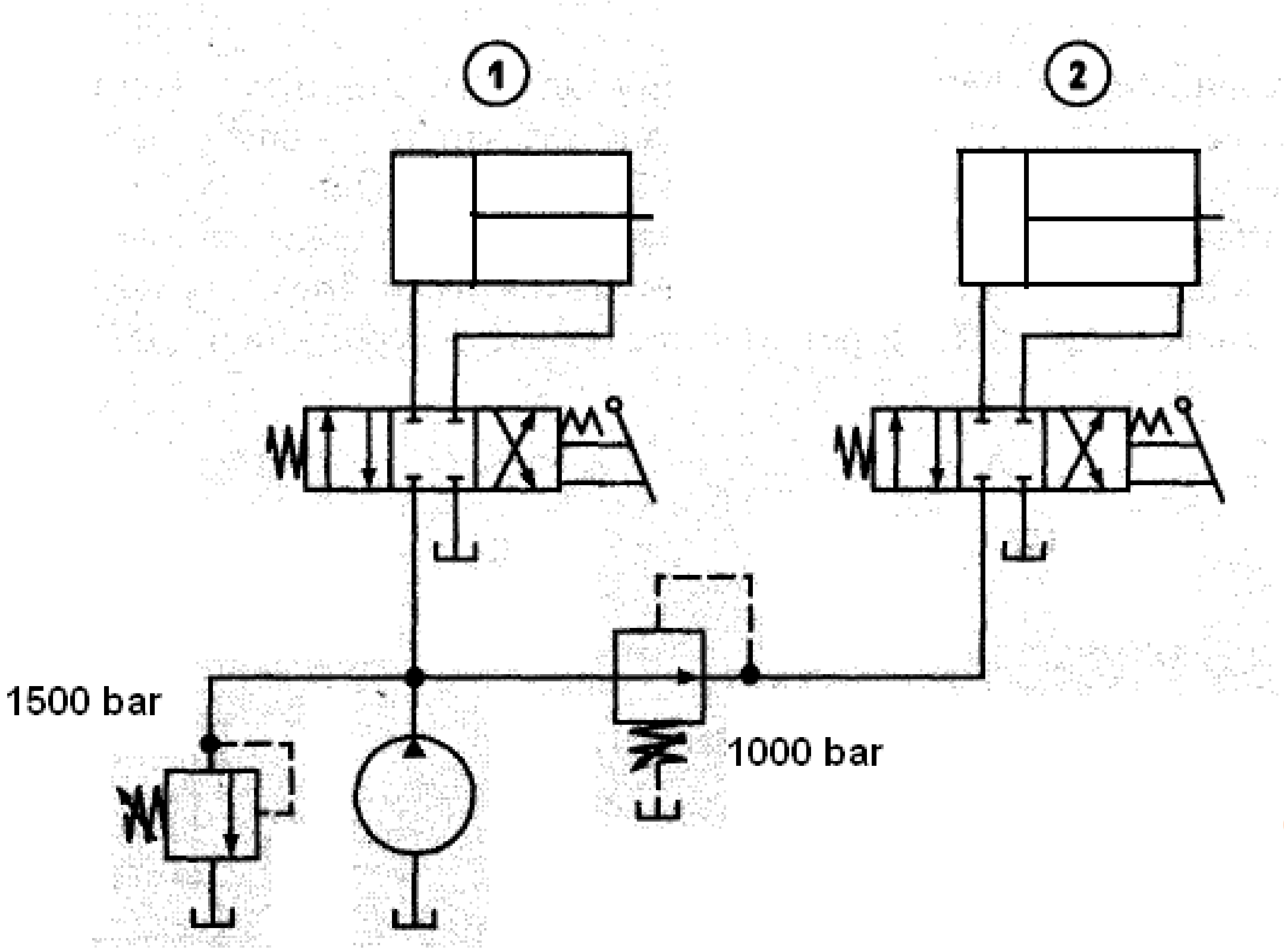
Symbol comparison

Pressure reducing valve



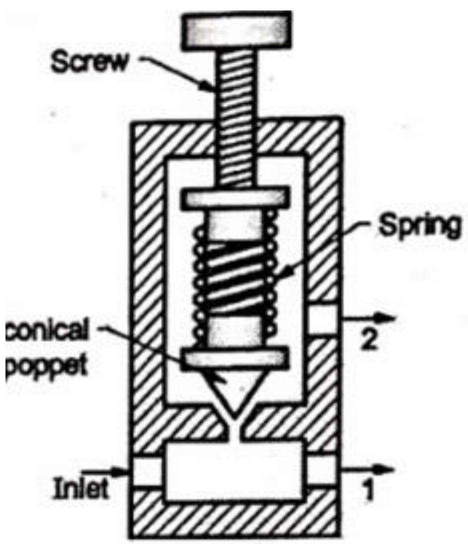
(a) Operation (b) Graphic symbol

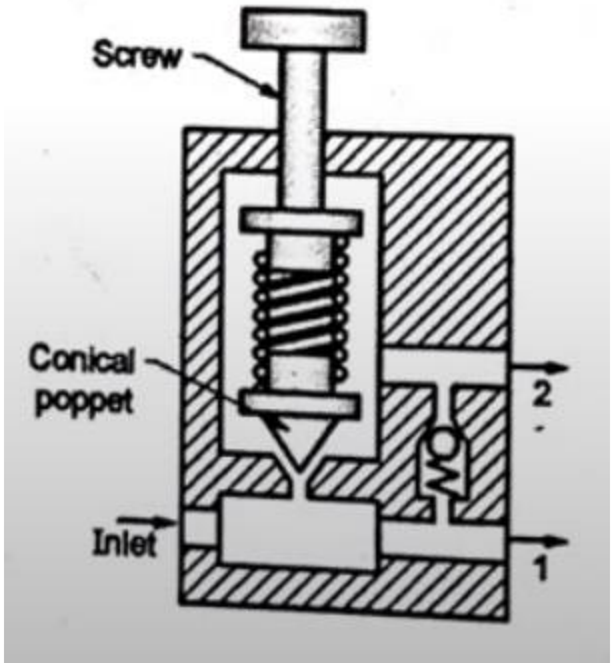
Application of Pressure Reducing Valve



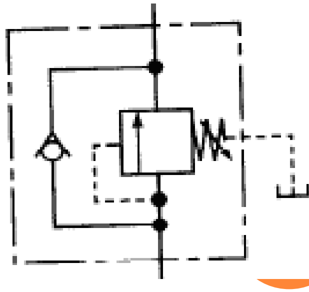
SEQUENCE VALVE

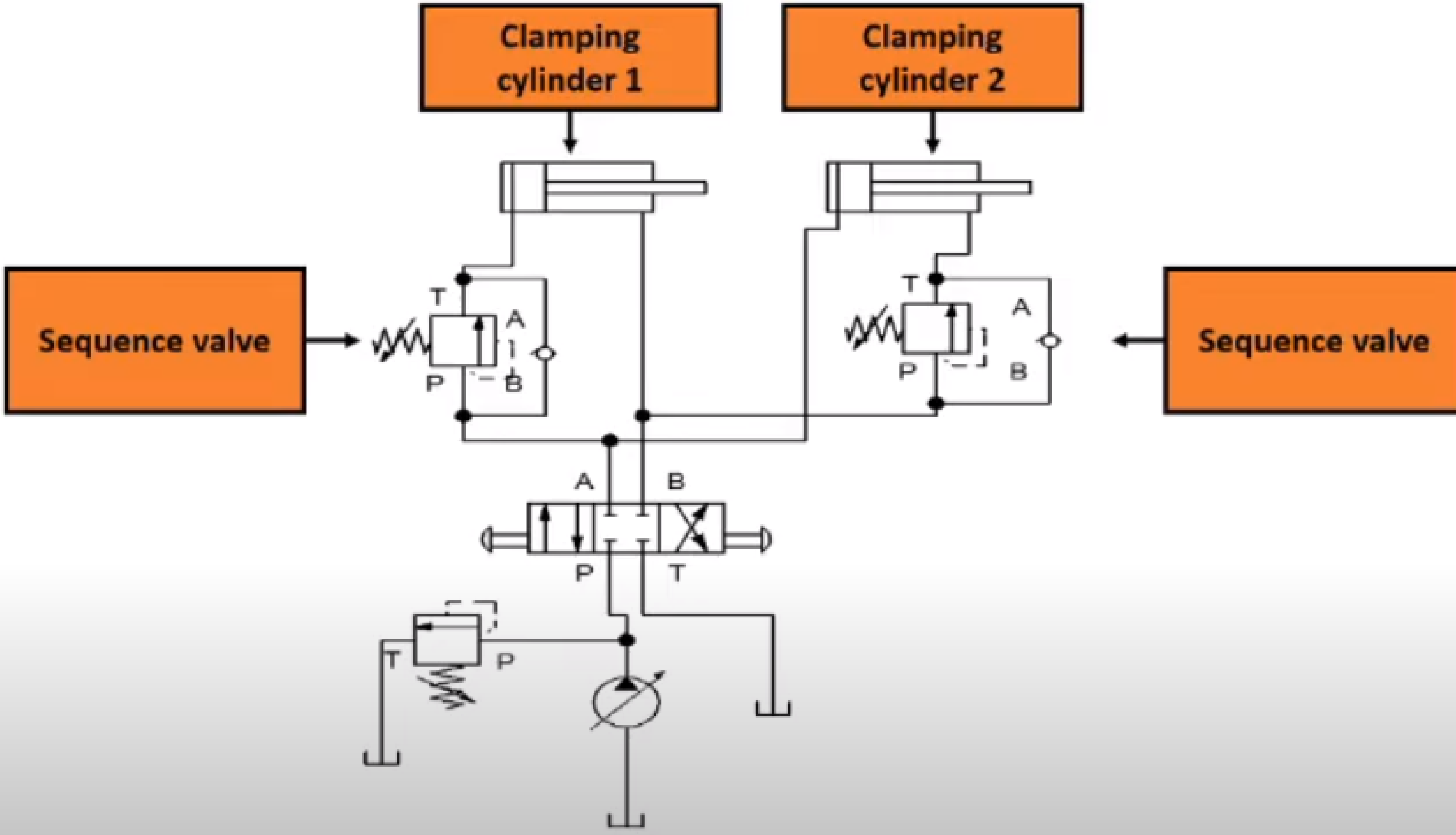
- *The sequence valves are used to control the fluid flow to ensure several operations in a particular order of priority in the system.*
- The sequence valves are another type of pressure control valves, which are also extensively used in hydraulic systems.
- These valves permit several operations to be completed in a sequential order, *i.e.*, one after another. For example, a pressure sequence valve used in a clamping and drilling circuit will permit the clamping operation to take place first and then the drilling operation is accomplished.
- The sequence valves are set to specific pressure levels so as to ensure the priorities of function.





Sequence valve




Clamping cylinder 1
Clamping cylinder 2
Sequence valve
Sequence valve
T
A
P
B
T
A
P
B
A
B
P
T
T
P

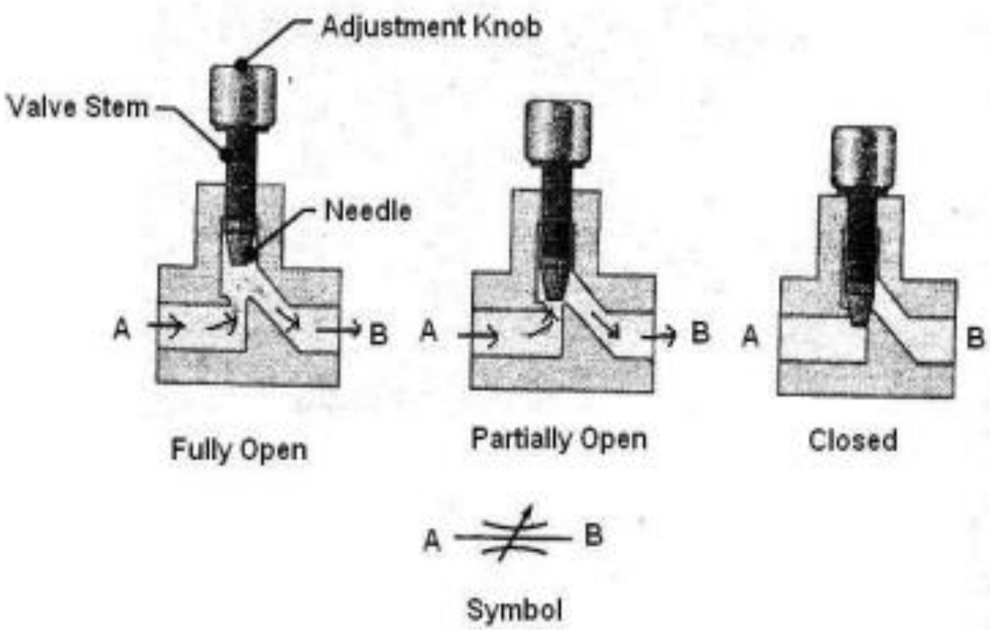
III. Flow Control Valve

- ✓ *Flow control valves, also known as* ***volume-control valves,*** *are used to regulate the rate of fluid flow to different parts of a hydraulic system.*
- ✓ Since control of flow rate is a means by which the speed of hydraulic machine elements is governed, therefore flow control valves are also known as ***speed-control valves.***
- ✓ The flow rate to a particular system component is varied by throttling or by diverting the flow.

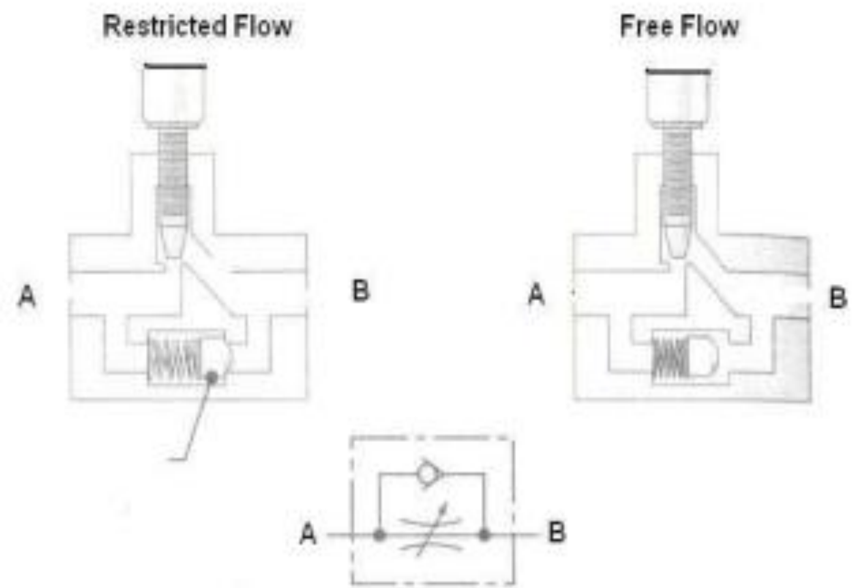
Types

- 1. Needle flow control valve
- 2. Pressure compensated flow control valve

NEEDLE FLOW CONTROL VALVE

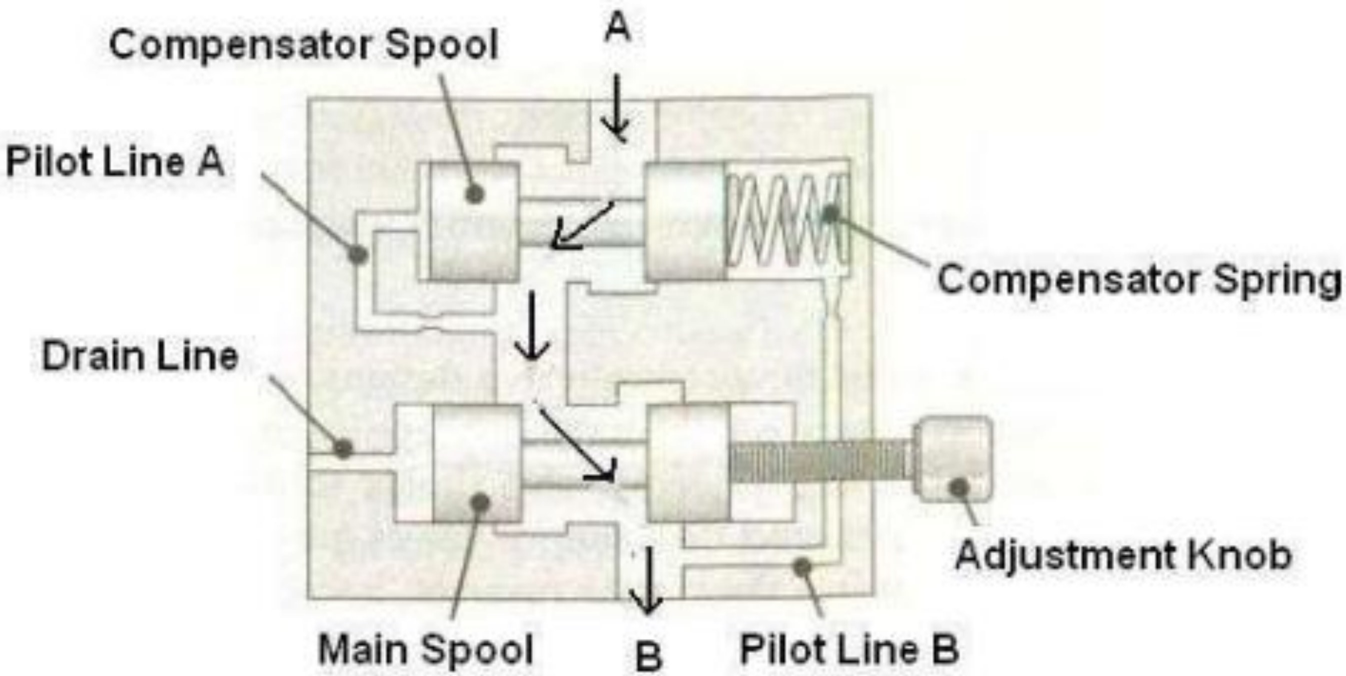


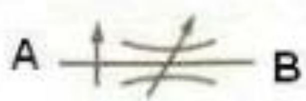
Needle Valve

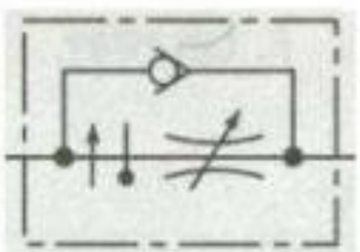


Needle Valve with Integral Check Valve

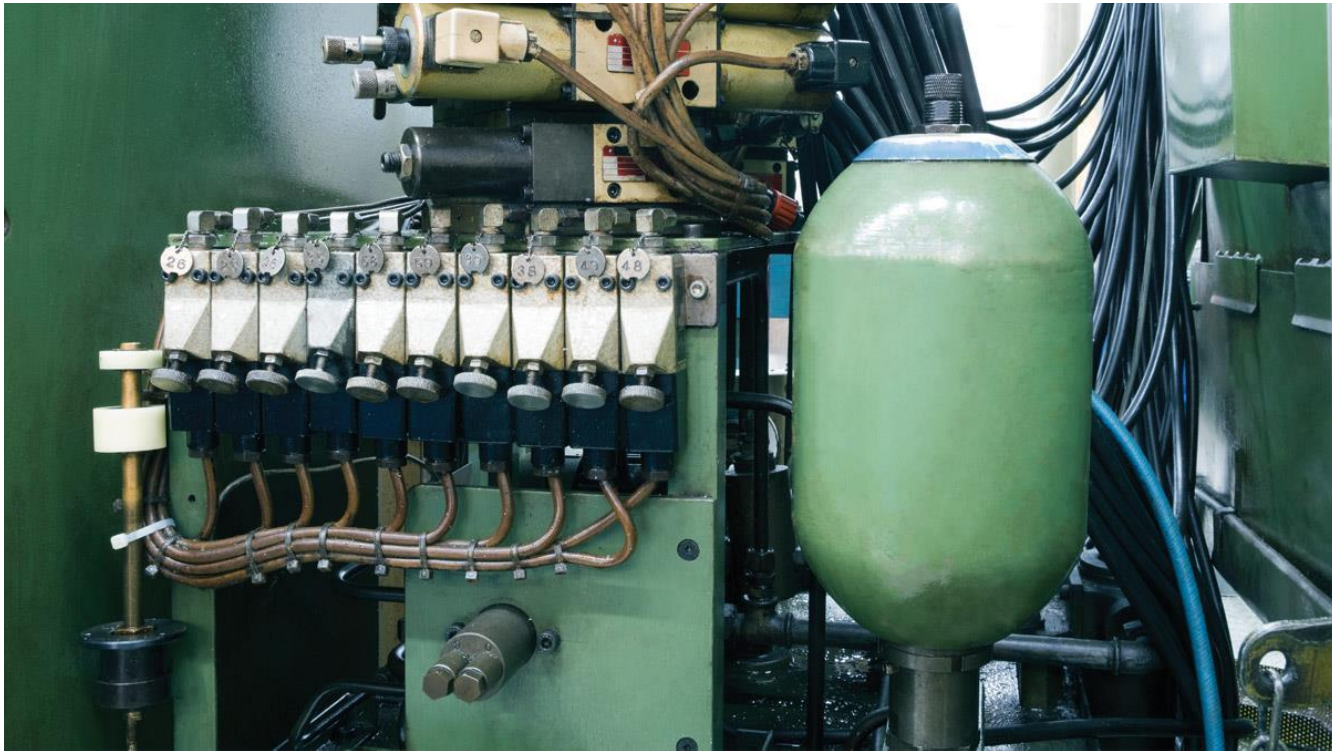
PRESSURE COMPENSATED FLOW CONTROL VALVE







ACCUMULATORS AND INTENSIFIERS



1.	*Fluid Reservoir :* ✓ Reservoirs basically are used to provide a storage facility for the hydraulic fluid used by the system. ✓ In addition, the reservoirs also serve to separate entrained air, remove contaminants, and dissipate heat from the hydraulic fluid.
2.	*Filters and Strainers :* ✓ Filters and strainers are devices for trapping/ removing contaminants. ✓ Since the long-term operation of a hydraulic system depends on the cleanness of the hydraulic fluid used, therefore filters are necessarily used to prevent any contaminants from entering the system. ✓ Strainers are nothing but coarse filters.
3.	*Heat Exchangers (or Hydraulic Coolers) :* ✓ Heat exchangers, also known as hydraulic coolers, are devices used to dissipate the heat generated in a hydraulic system. ✓ We know that heat is generated in all hydraulic systems. The main sources of heat include, the pump, motor, pressure relief valves, and flow control valves. Much of this heat is transferred to the hydraulic fluid, causing a rise in fluid temperature. Since all hydraulic fluids exhibit a limited temperature range over which the viscosity and lubricating characteristics are optimum, the heat must be dissipated to ensure satisfactory operation. This function is accomplished by the heat exchangers.
4.	*Accumulators :* ✓ An accumulator, also known as *pressure accumulator,* is a device which can store hydraulic (pressure) energy. ✓ Accumulators can be used for pressure compensation, pulse damping, leakage compensation, emergency power, auxiliary pressure, and several other applications.

5. *Intensifiers :* ✓ An intensifier, also known as ***pressure booster,*** is a device used to compress the hydraulic fluid by a pressure greater than the system pressure generated by the primary pump.

✓ The intensifier convert a large-volume, low-pressure hydraulic fluid supply to a proportionately small-volume, high-pressure output.

6. ***Pressure gauges :*** ✓ Pressure gauges are used to measure the fluid pressure at various points in the system.

✓ Pressure measurement is considered as an important means of troubleshooting faulting operating hydraulic circuits. Pressure measurement can provide a good indication of leakage problems and faulty components such as pumps, motor, valves, and actuators. So pressure gauges are essential in any hydraulic system.

7. ***Pressure and Temperature Switches :*** ✓ ***A pressure switch*** is an instrument that automatically senses a change in pressure and opens or closes an electrical switching element when a predetermined pressure point is reached.

✓ ***A temperature switch*** is an instrument that automatically senses a change in temperature and opens or closes an electrical switching element when a predetermined temperature point is reached.

8. ***Shock Absorbers :*** ✓ A shock absorber is a device that brings a moving load to a gentle rest through the use of metred hydraulic fluid.

✓ The shock absorber accomplishes the 'smooth' deceleration by metering hydraulic fluid through orifices, converting work and kinetic energy into heat which is dissipated.

9. ***Hydraulic Piping :*** ✓ The function of hydraulic piping is to contain and conduct the hydraulic fluid from one port of the system to another.

✓ The design of the fluid conductors is just as important as the design of other components of a hydraulic system.

What are Accumulators ?

An accumulator is basically a pressure storage reservoir in which a non-compressible hydraulic fluid is retained under pressure from an external source.

- ✓ In other words, hydraulic accumulator is a device used to store the energy of liquid under pressure and make this energy available as a quick secondary source of power to hydraulic machines (such as presses, lifts, and cranes).
- ✓ ***Example :*** In case of hydraulic crane or lift, the liquid under pressure needs to be supplied only during the upward motion of the load. This energy is supplied from hydraulic accumulator. But when the lift is moving downward, no large external energy is required and during that period the energy from the pump is stored in the accumulator.
- ✓ *Thus the function of hydraulic accumulator is analogous to that of the flywheel of a reciprocating engine and a **capacitor** in an electronic circuit.*
- ✓ ***Definition :*** A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source (such as pump) against some dynamic force (such as weight or gravity, mechanical force by springs, or pressurised gas).

8.2.3. Types of Accumulators

Accumulators are classified in terms of the manner in which the load is applied. The three basic types of accumulators used in hydraulic systems are :

1. Weight-loaded (or dead-weight) accumulators,
2. Spring-loaded accumulators, and
3. Gas-loaded accumulators.
    1. Non-separator type, and
    2. Separator type.
        (*a*) Piston type, (*b*) Diaphragm type, and (*c*) Bladder type.

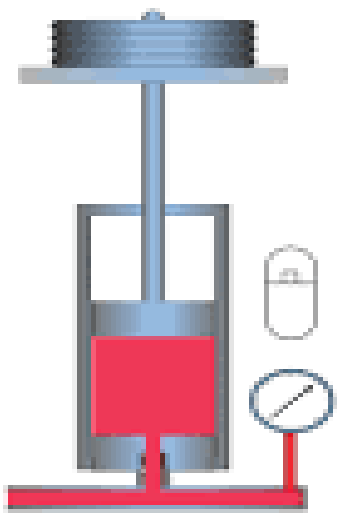


Fig. 2: Weighted accumulator

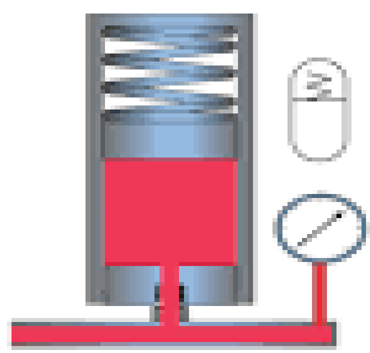


Fig. 3: Spring-loaded accumulator

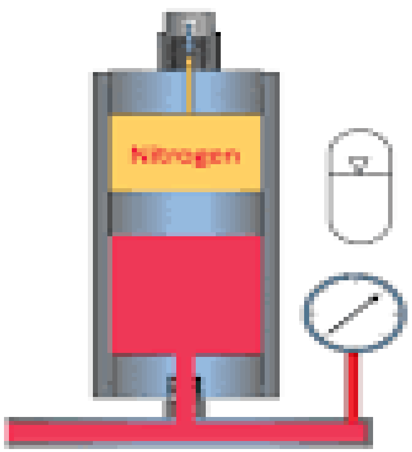
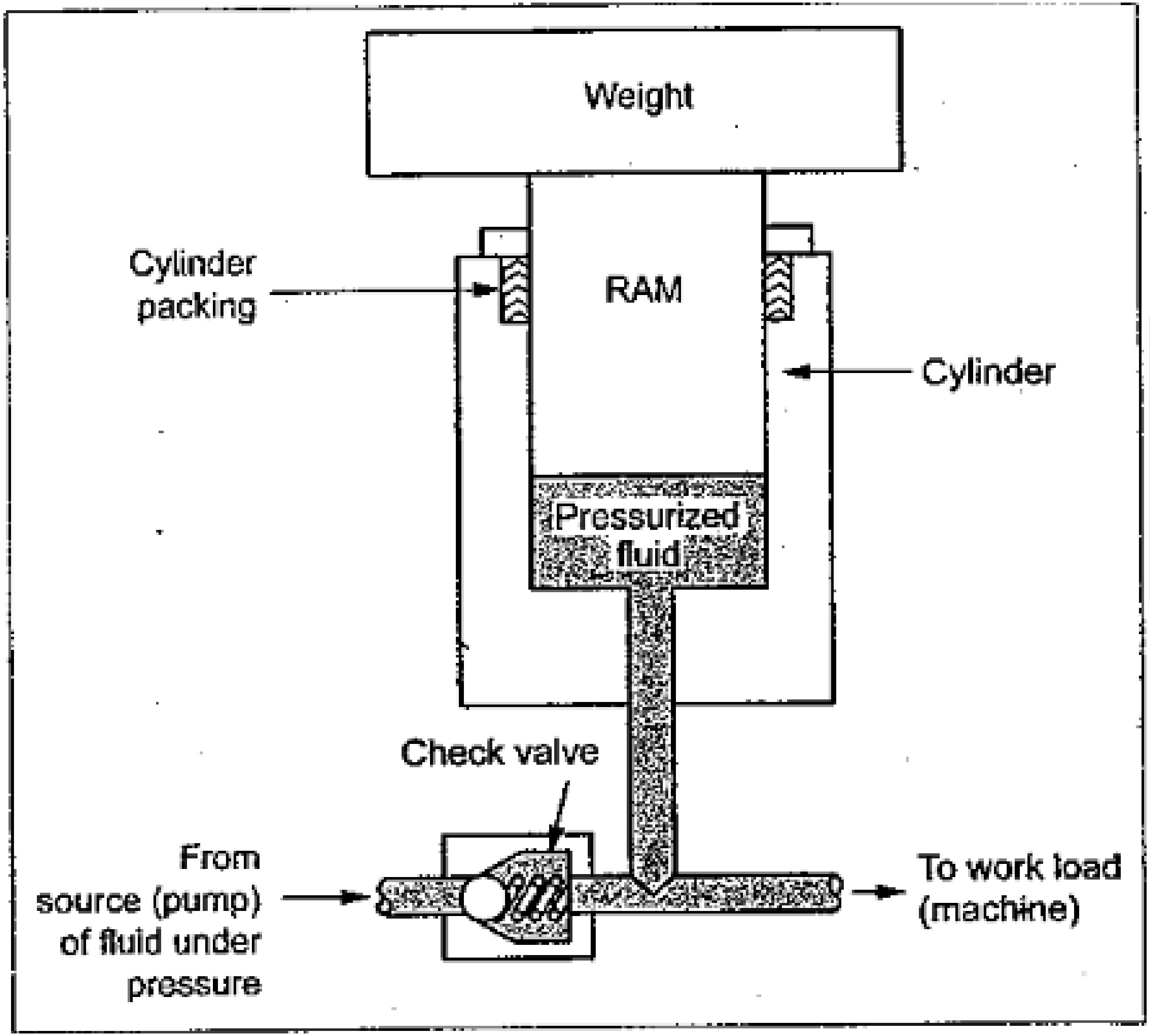
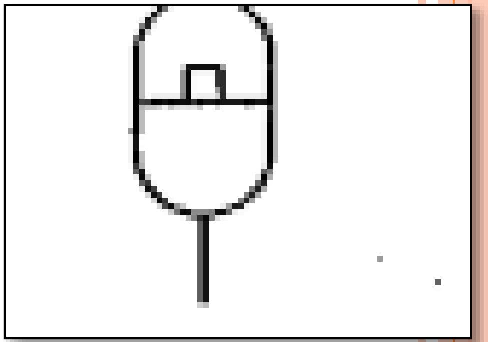


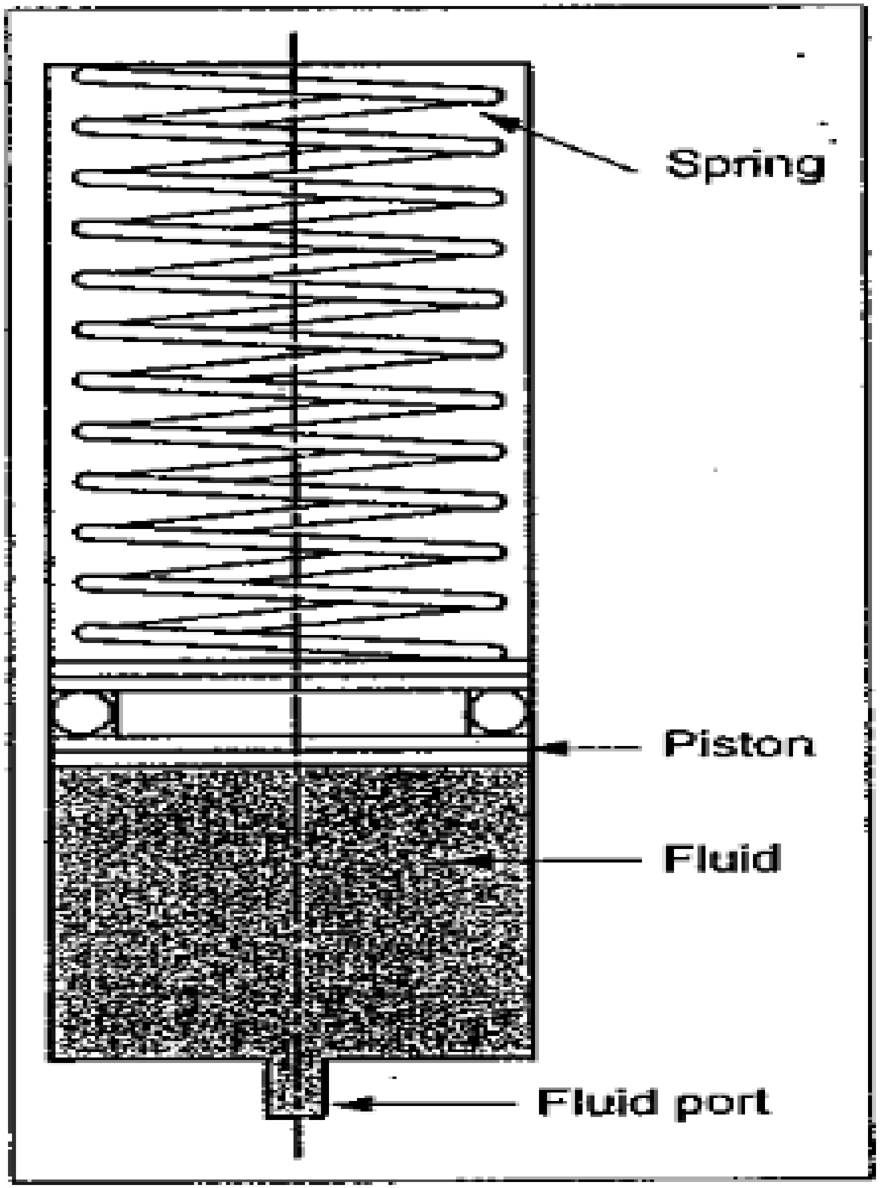
Fig. 4: Gas-charged accumulator

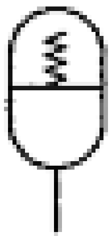
Dead-weight Accumulator



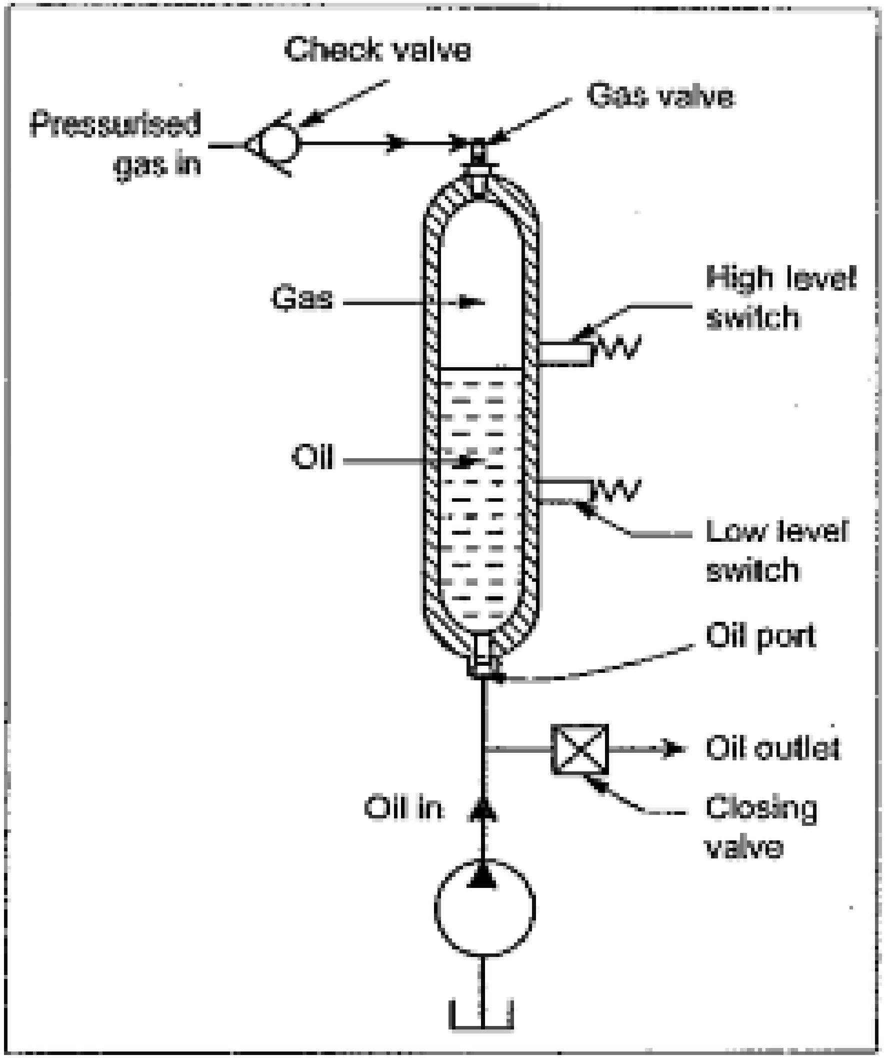


Spring Loaded Accumulator





Non-Separator Type



Separator Type

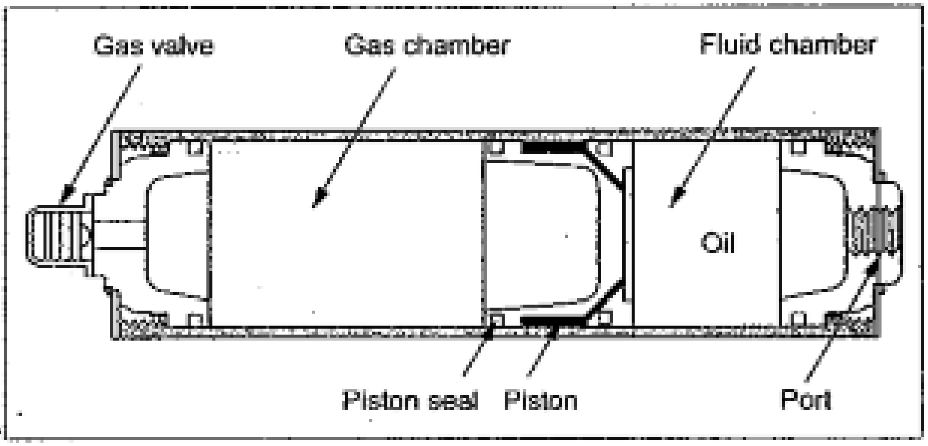


Fig. 8.4. Piston type accumulator

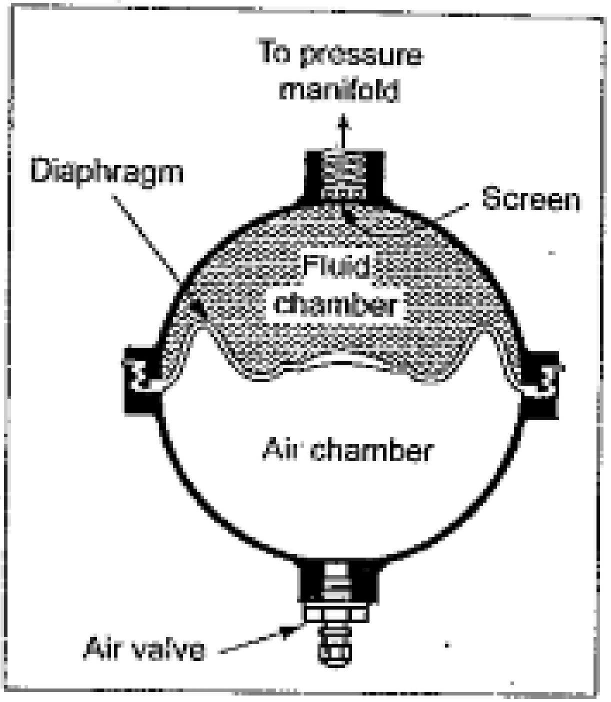


Fig. 8.5. Diaphragm-type gas-loaded accumulator

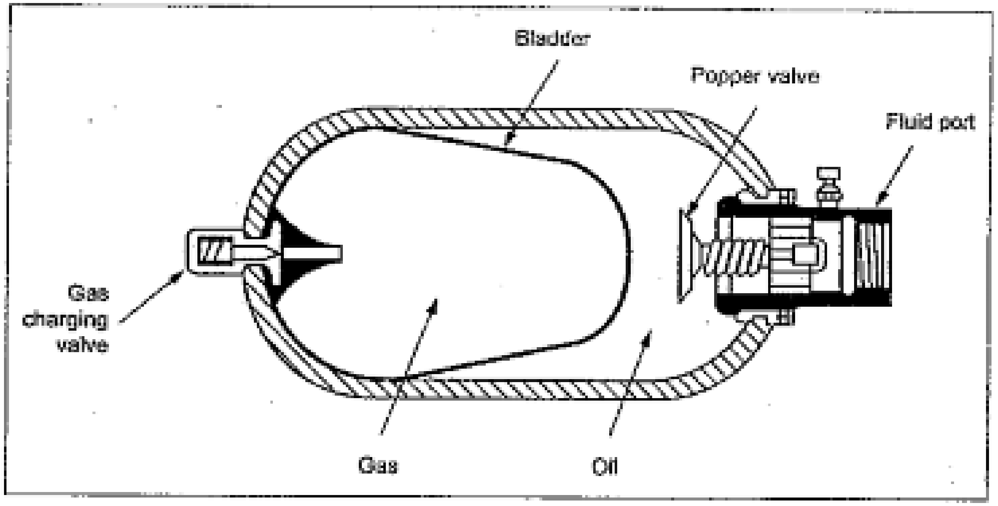
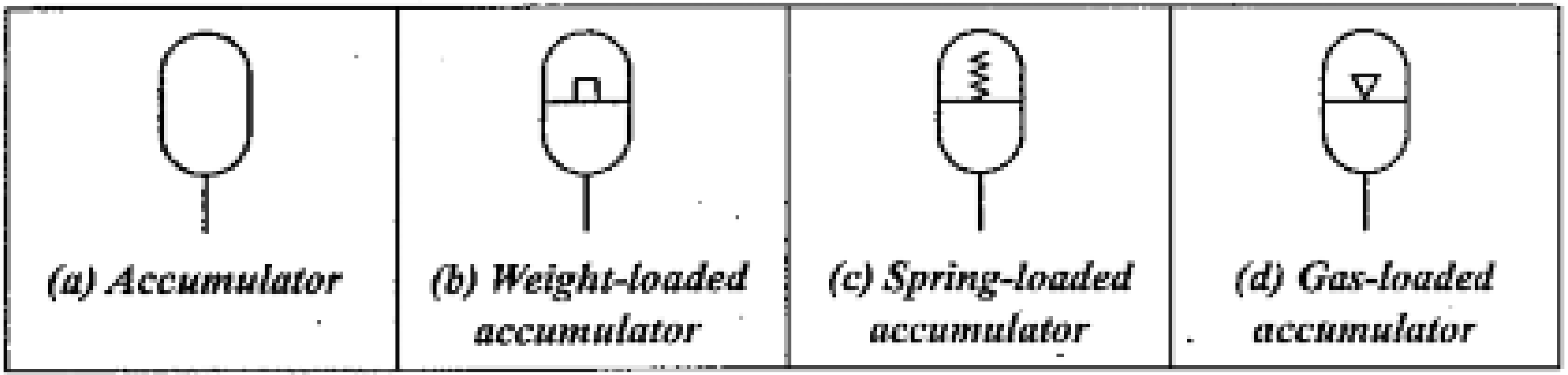


Fig. 8.6. Bladder-type gas-loaded hydraulic accumulator

Accumulator symbols



Sizing of Accumulator

Analysis of Weight Loaded Accumulator

Fig.8.12 shows a simple weight-loaded type accumulator.

Capacity of accumulator : The maximum amount of energy that the accumulator can store is known as the capacity of the accumulator.

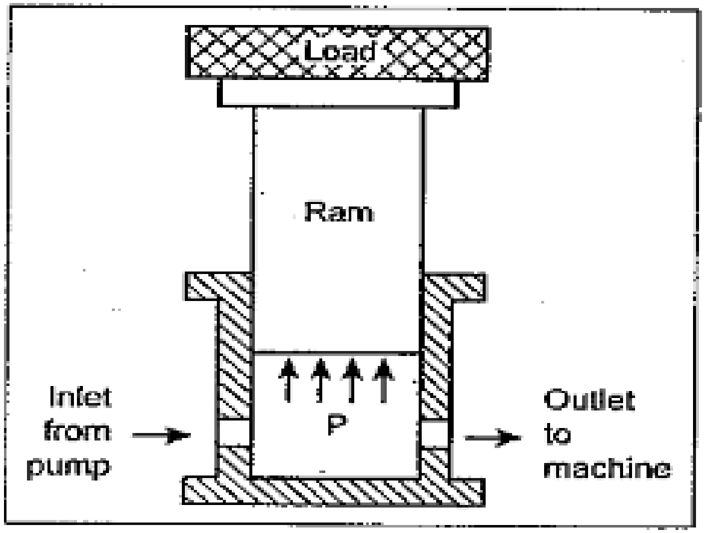


Fig. 8.12. Weight-loaded type accumulator

Derivation :

Let A = Area of the sliding ram = $\frac{\pi}{4} D^2$,

D = Diameter of the ram,

L = Stroke or lift of the ram,

P = Intensity of pressure of hydraulic fluid supplied by the pump, and

W = Total weight of the ram including the weight of the dead-load on the ram.

We know that, $W = P \times A$

Work done in lifting the ram = W × Lift of ram

$= W \times L = P \times A \times L$ $[\because W = P \times A]$

But, $\begin{Bmatrix} \text{Work done in} \\ \text{lifting the ram} \end{Bmatrix} = \begin{Bmatrix} \text{Energy stored in} \\ \text{the accumulator} \end{Bmatrix} = \begin{Bmatrix} \text{Capacity of the} \\ \text{accumulator} \end{Bmatrix}$

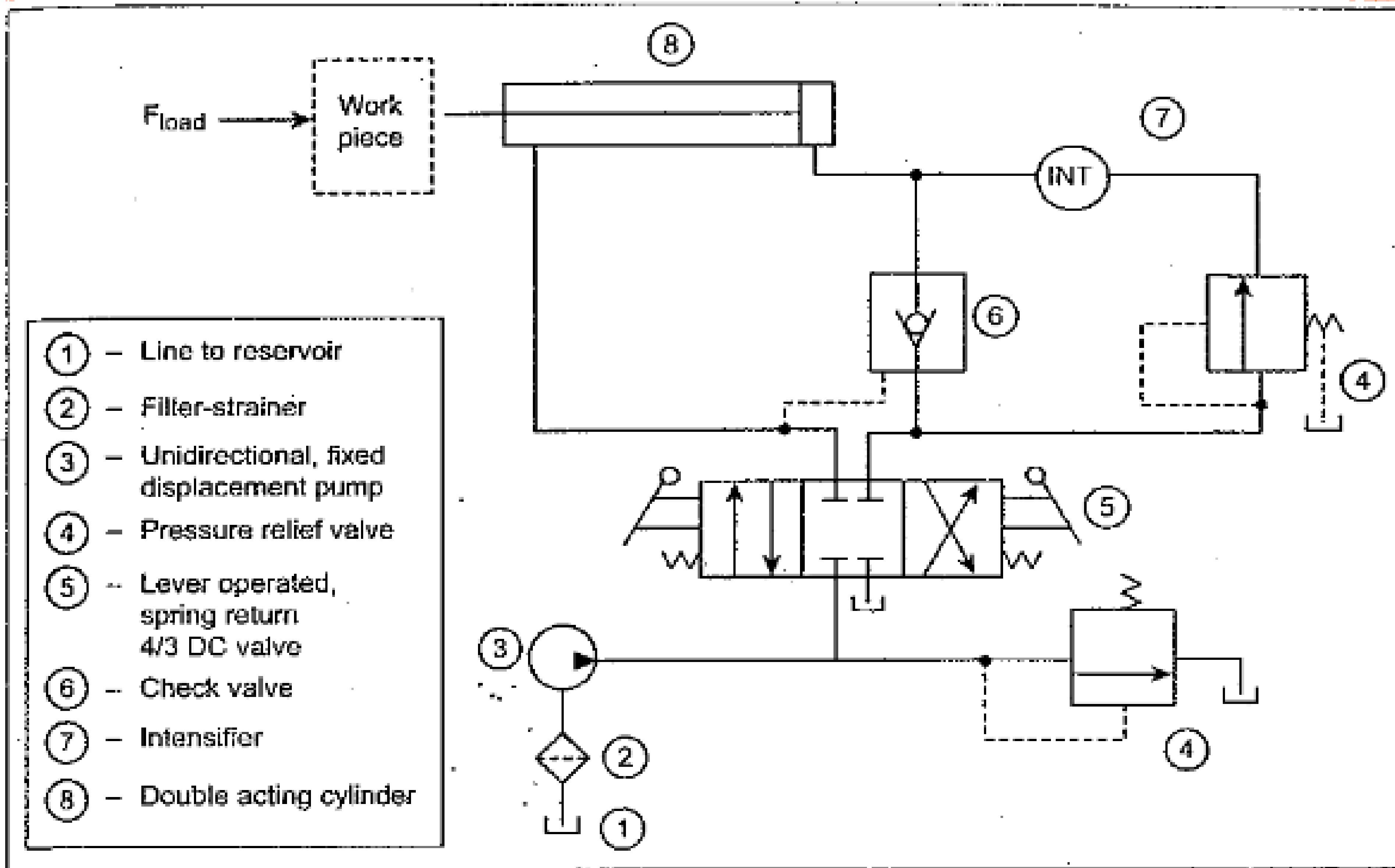
$\therefore$ $\boxed{\text{Capacity of the accumulator} = P \times A \times L}$ ... (8.1)

$= P \times$ Volume of accumulator ... (8.2)

Intensifier/Pressure Booster

- ✓ Pressure intensifiers, also known as ***pressure boosters***, are used to compress the liquid in a hydraulic system to a value above the pump discharge pressure.
- ✓ In other words, *a hydraulic intensifier is a device which converts a large-volume, low-pressure fluid supply into a proportionately small-volume, high-pressure fluid outlet.*
- ✓ The intensifier is usually located in between the pump and the machine (*e.g.*, press, crane, lift) that needs high pressure liquid for its operation.
- ✓ The action of the intensifier is similar to that of a ***step-up electrical transformer.***
- ✓ It finds its application at places where a liquid of very high pressure is to be developed from available low pressure. Typical applications include hydraulic presses, riveting machines, and spot-welders.

Pressure Intensifier Circuit



Applied Hydraulics and Pneumatics

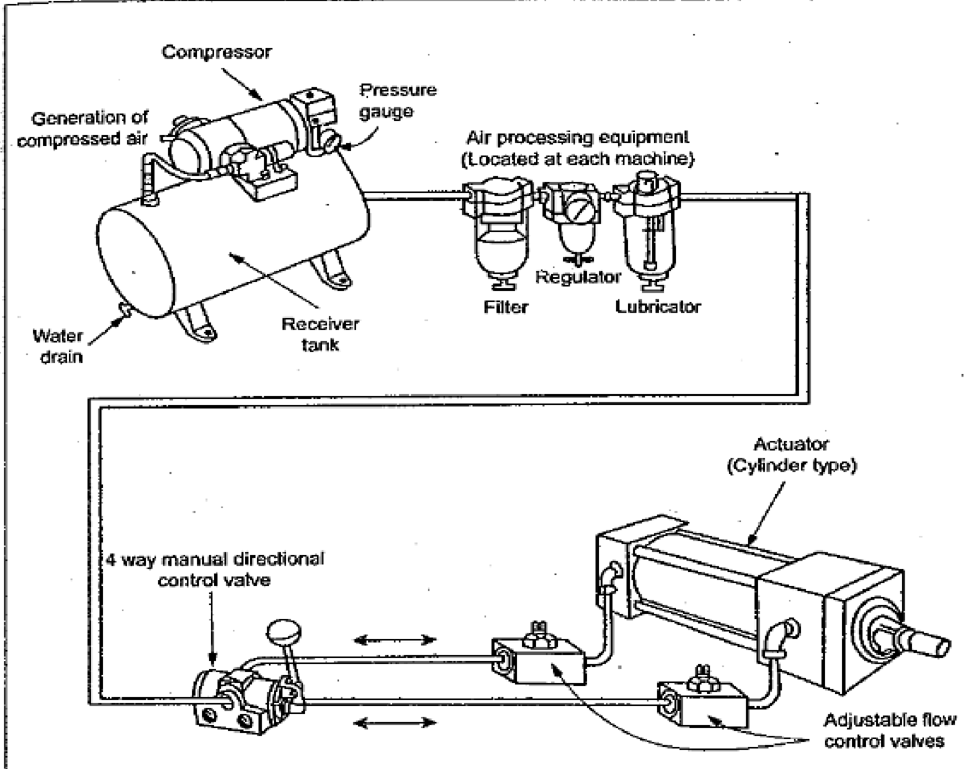
Unit-IV

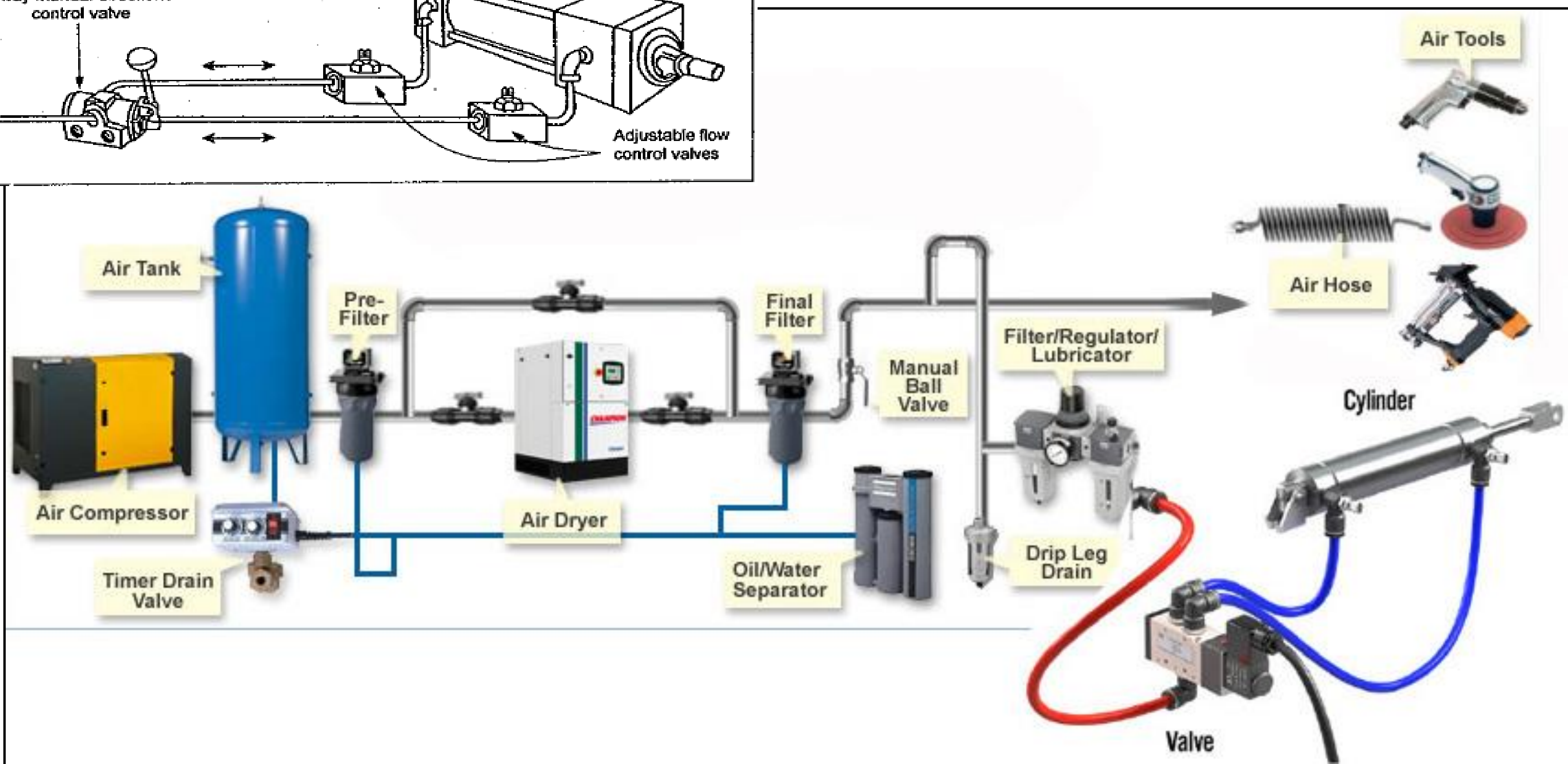
Pneumatic System and Components

Basics of Pneumatics

Introduction

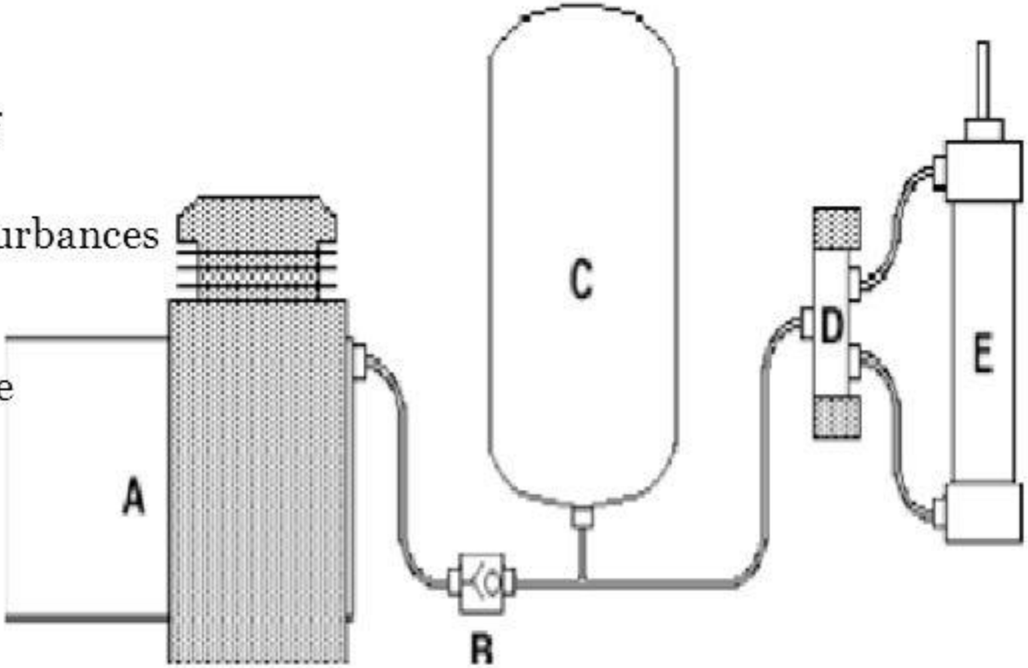
- ✓ ***Definition :*** *The pneumatics may be defined as that branch of engineering-science which deals with the study of the behaviour and application of compressed air.*
- ✓ Like hydraulics, pneumatics is a branch of the fluid power technology. Thus the pneumatics is the technology that deals with the generation, control, and transmission of power using pressurised air.


Compressor
Pressure gauge
Generation of compressed air
Air processing equipment (Located at each machine)
Filter
Regulator
Lubricator
Water drain
Receiver tank
Actuator (Cylinder type)
4 way manual directional control valve
Adjustable flow control valves


Air Tools
Air Tank
Pre-Filter
Final Filter
Air Hose
Manual Ball Valve
Filter/Regulator/Lubricator
Cylinder
Air Compressor
Air Dryer
Timer Drain Valve
Oil/Water Separator
Drip Leg Drain
Valve

Basic Pneumatic System

- **A) Compressor**
  - Pressurizes Air
  - Typically attached to tank for storage
  - Often is a centralized supply for multiple devices
- **B) Check Valve**
  - One way valve
  - Prevents backflow into compressor
  - Prevents compression loss when off
- **C) Accumulator**
  - Smooth air flow and unwanted disturbances
- **D) Directional Valve**
  - Direct Air flow
  - Stores energy and reduce turbulence
  - Electrical or manual operation
- **E) Actuator**
  - Transfers air energy into motion
  - Ex. Air Chisel



Advantages of pneumatic system over Hydraulic system

1. Since the weight density of gas is many times lesser than liquid, therefore inertia effect of pneumatic components are lesser than hydraulic system components. Thus the force required to accelerate gas (air) is much lesser than that required to accelerate an equal volume of oil.
2. Since viscosity of air is much lesser than that of oil, therefore the pneumatic systems experience lesser frictional pressure and power losses than the hydraulic systems.
3. Unlike in hydraulic systems, pneumatic systems can exhaust its fluid medium (air) to the atmosphere after completing its assigned task. This reduces the requirements of special designs for reservoirs and leak-proof systems.
4. Pneumatic systems are comparatively cheaper in cost than the hydraulic systems.
5. Pneumatic systems provide better operational advantages when compared to hydraulic systems.
6. Compared to hydraulic systems, pneumatic systems are lesser in weight.
7. Unlike in hydraulic systems, leakage of air in pneumatic systems will not affect the system performance very much (because the air compressor supplies the pressurised air continuously).

Disadvantages of pneumatic system over Hydraulic system

The main disadvantages of pneumatic systems are given below :

1. Due to the high compressibility of air, pneumatic systems cannot provide precise actuator control and precise positioning control.
2. Due to compressor design limitations, pneumatic systems can be applied only to low-pressure (less than 17 bars) applications; whereas hydraulic systems can be applied to high-pressure (upto 700 bars) applications.

Applications

1. Stamping,
2. Drilling,
3. Hoisting,
4. Punching,
5. Assembling,
6. Clamping,
7. Riveting,
8. Materials handling,
9. Logic controlling, and
10. Hammering.

Air Compressors and Fluid Conditioners

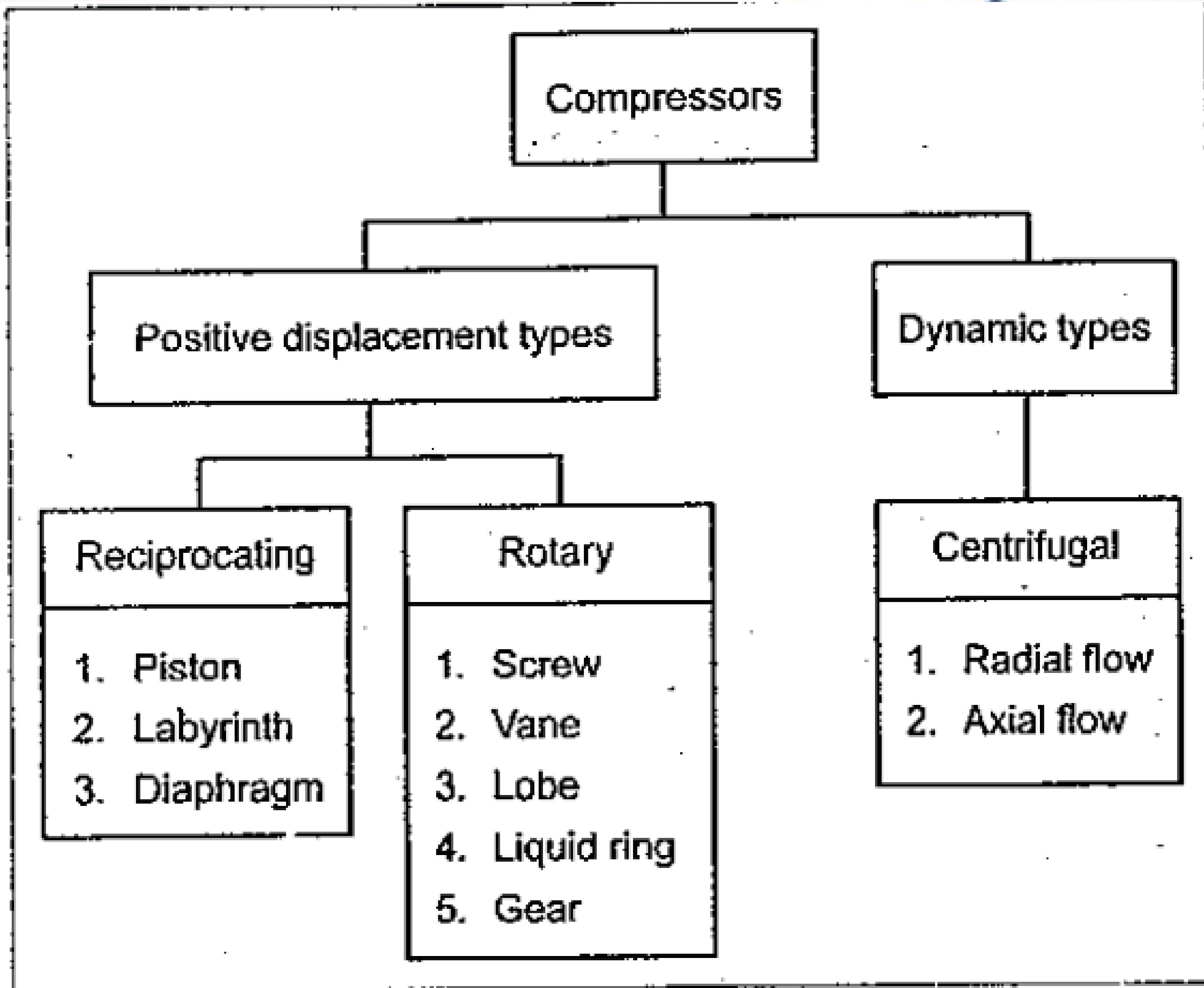
Air Compressor

- The machine which takes in air or any other gas at low pressure and compresses it to high pressure are called compressor.

Functioning of Air Compressor

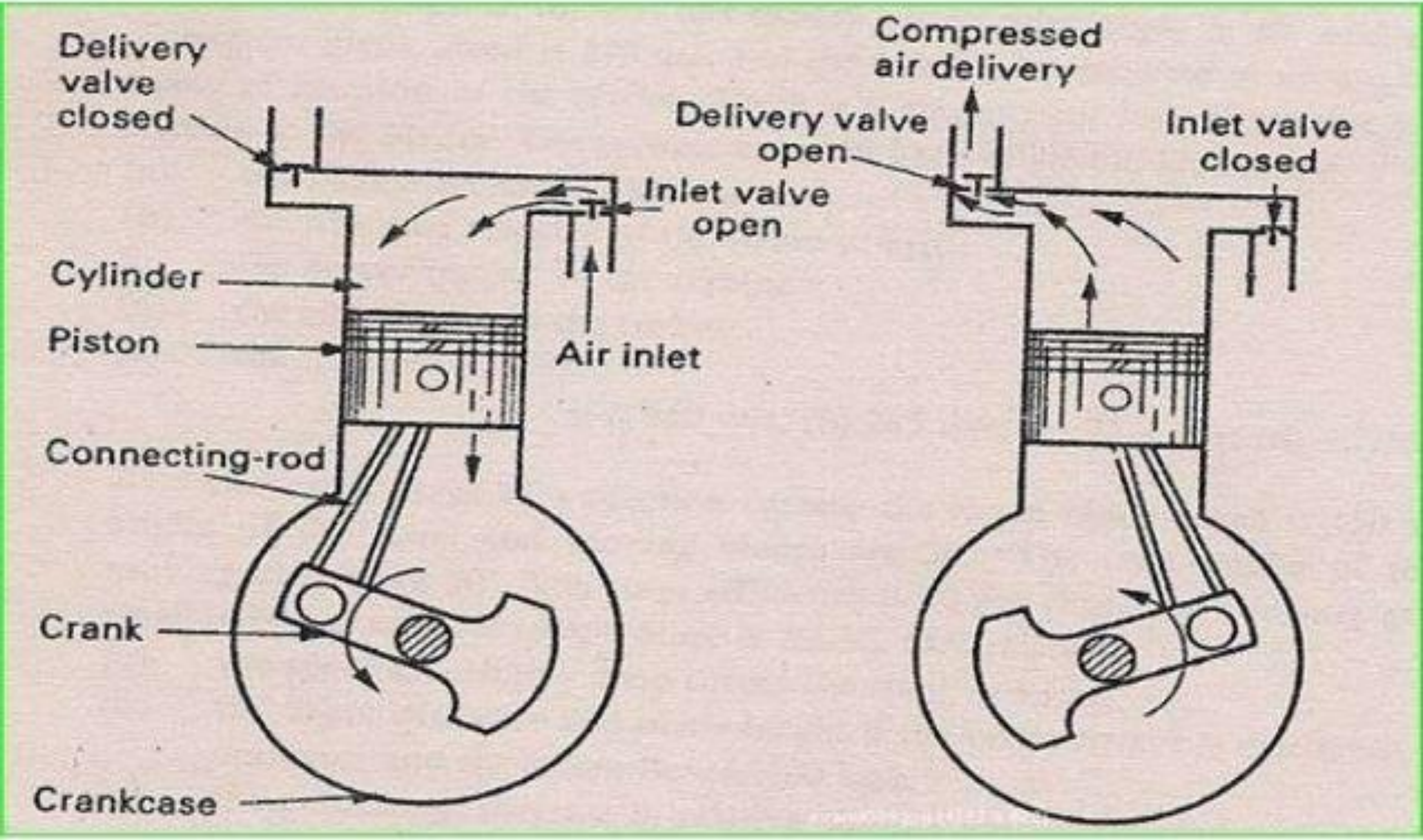
- Air is compressed and stored inside the air receiver.
- The function of the air compressor is to reduce volume and induce pressure in the compressed air.
- The main function of the compress is to convert electric energy into kinetic energy.

Classification of Air Compressors



Single Cylinder Compressor

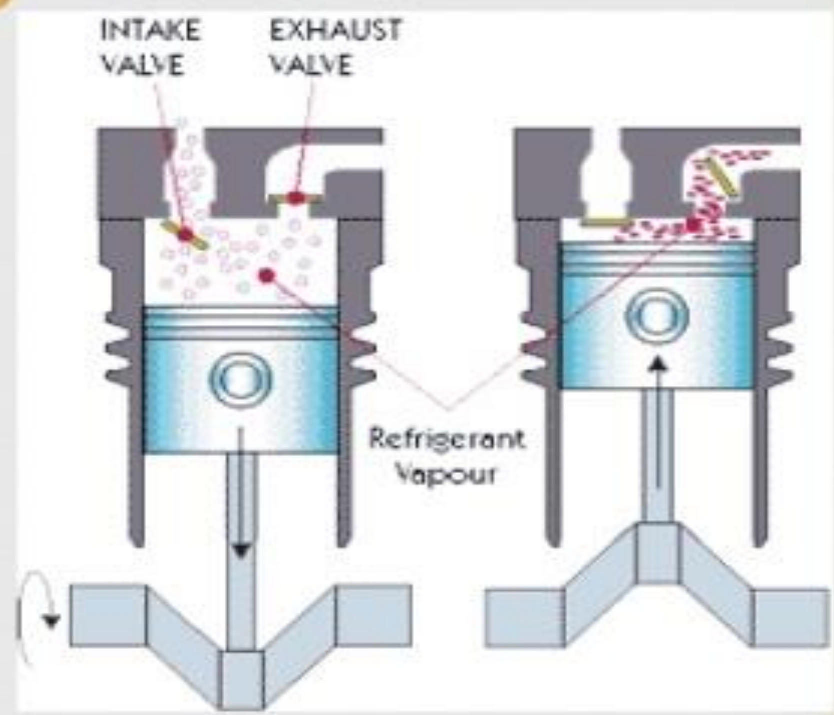
Single Cylinder Compressor



Single Cylinder Compressor

Principle of Operation

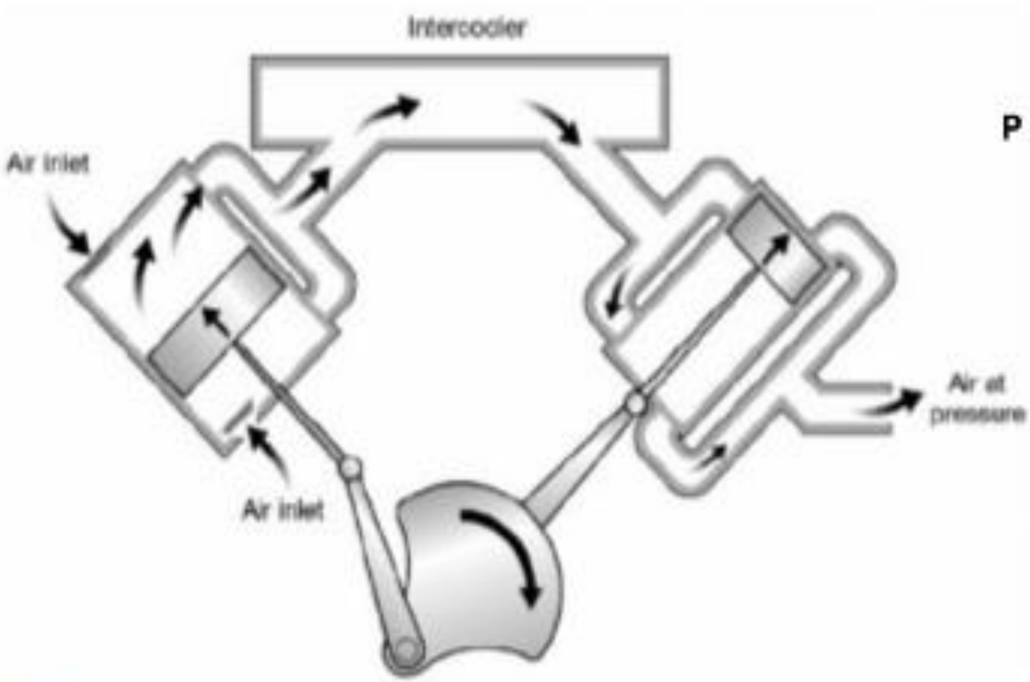
- Fig shows single-acting piston actions in the cylinder of a reciprocating compressor.
- The piston is driven by a crank shaft via a connecting rod.
- At the top of the cylinder are a suction valve and a discharge valve.
- A reciprocating compressor usually has two, three, four, or six cylinders in it.

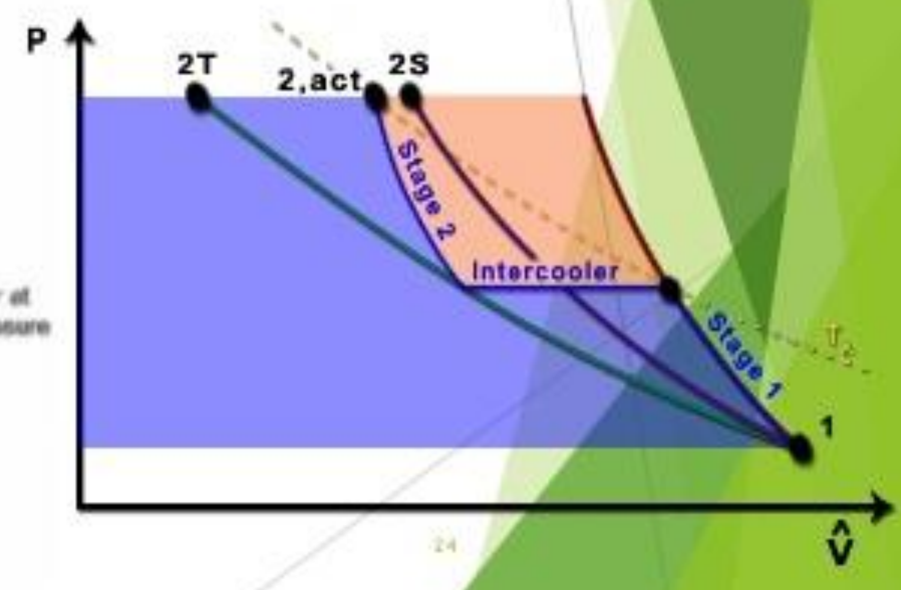


Multi stage air compressor

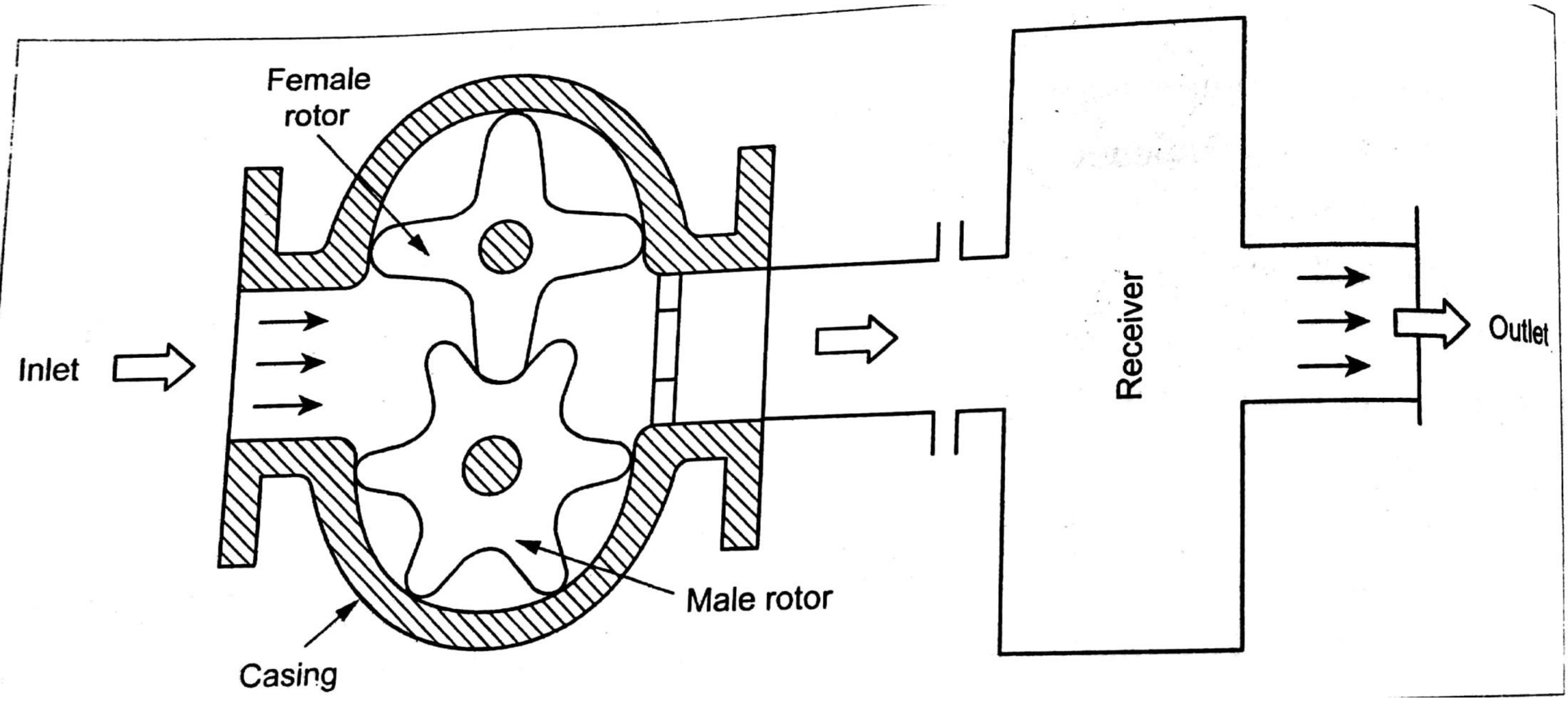
- Depending on the number of compression stages, there are **single stage** or **multi stage** compressors. In multi stage compressors, air is cooled in between a stage of compression with the help of an intercooler.

Two-cylinder, two-stage reciprocating compressor



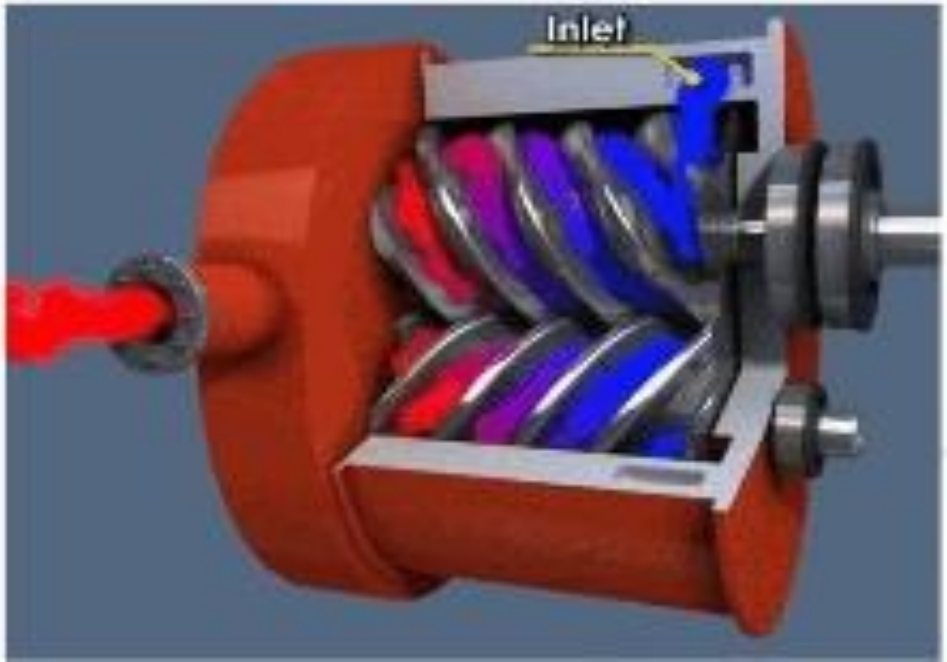


Screw Compressor

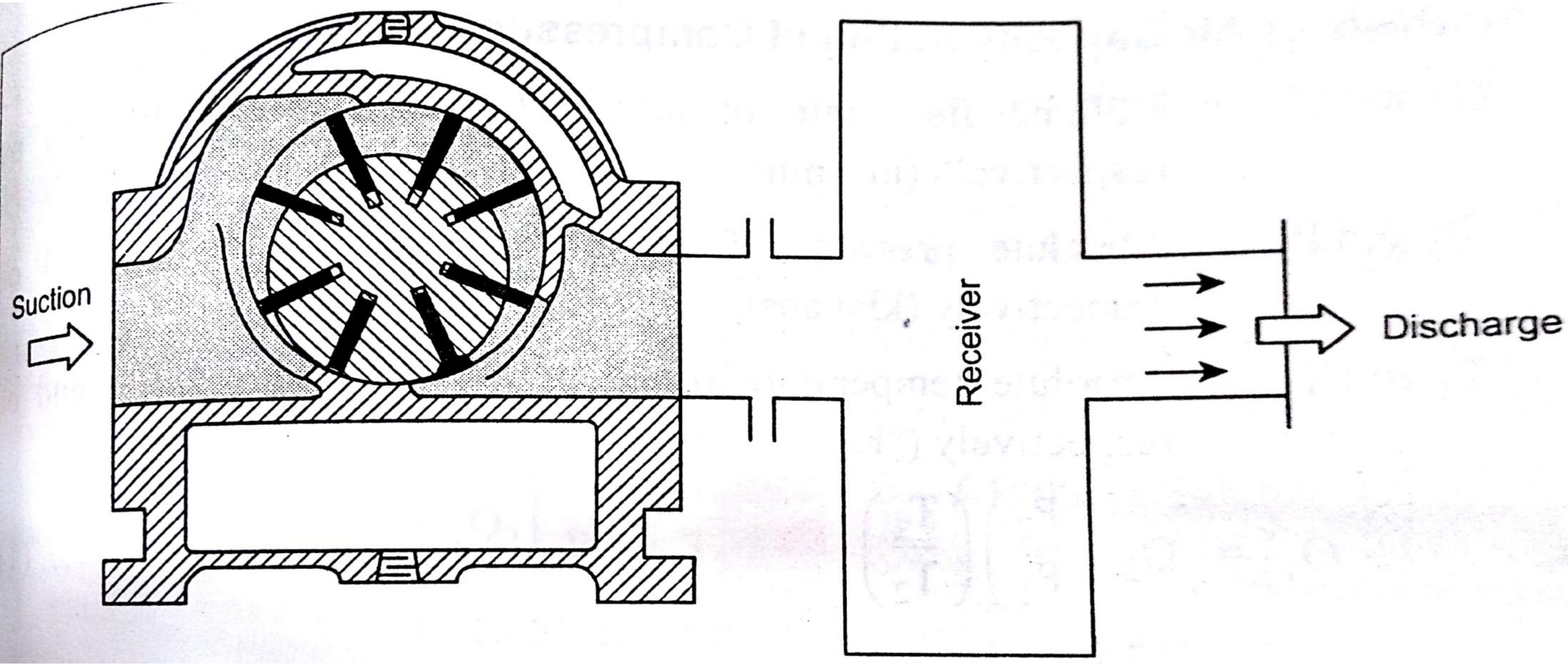


Rotary screw compressors:

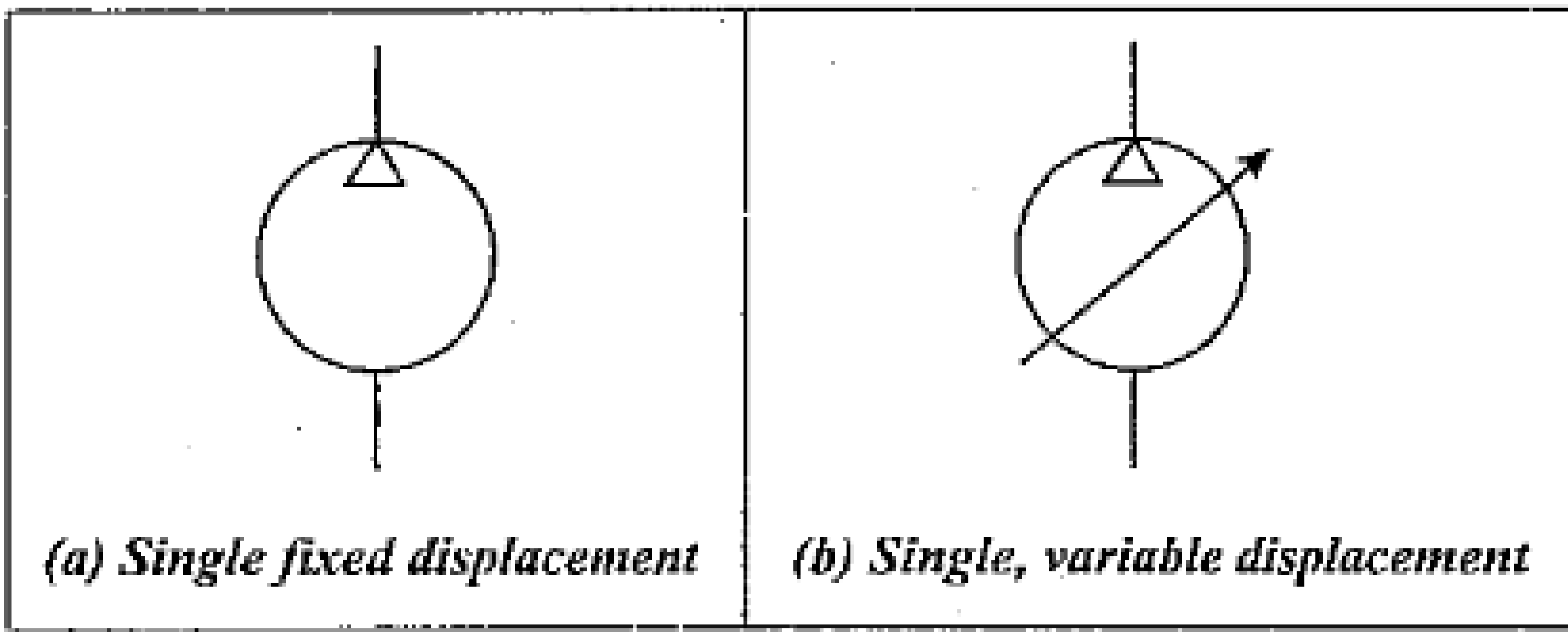
- Rotary screw compressors use two meshed rotating positive-displacement helical screws to force the air into a smaller space (see figure).
- These are usually used for continuous operation in commercial and industrial applications and may be either stationary or portable.
- Because of simple design and few wearing parts, rotary screw air compressors are easy to install, operate, and maintain.



Rotary vane compressor



Graphical Symbols



(a) Single fixed displacement

(b) Single, variable displacement

Fluid Conditioners

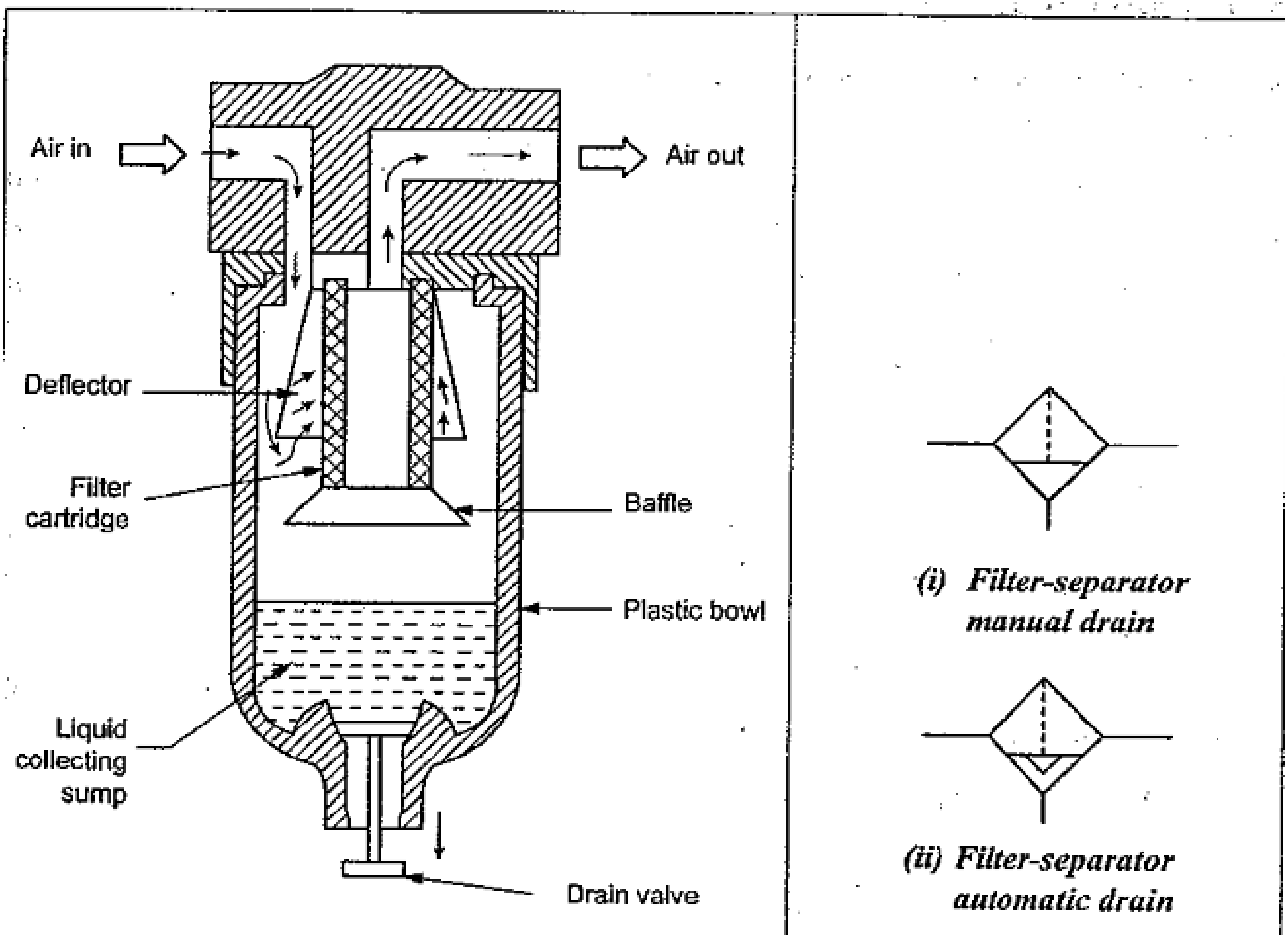
Purpose : The purpose of fluid conditions is to make the compressed air more acceptable and suitable fluid medium for the pneumatic system components as well as for operating personnel.

Elements of fluid conditioners

The important fluid conditioners are :

1. Filters,
2. Regulators,
3. Lubricators,
4. Mufflers, and
5. Air dryers.

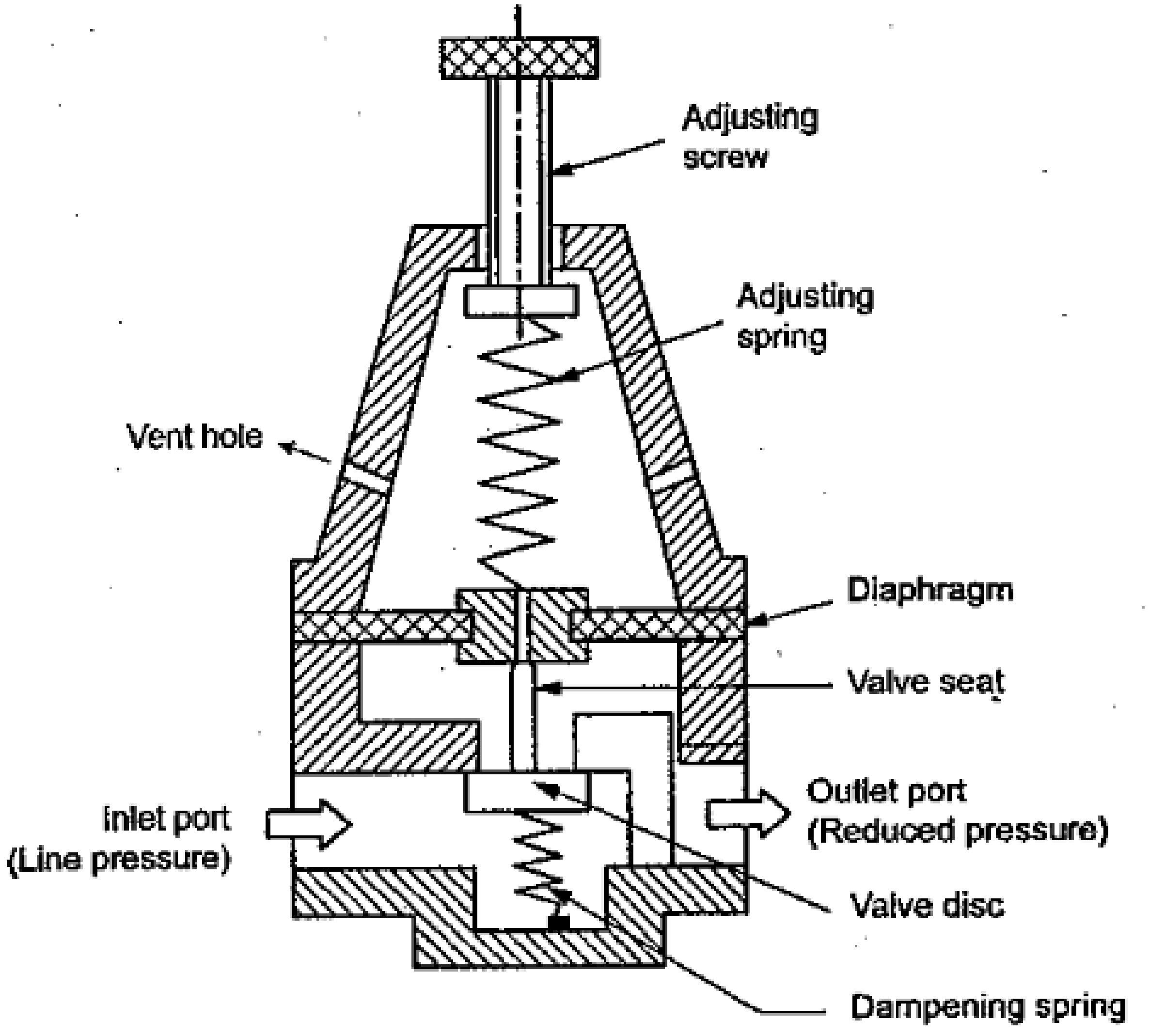
Air Filters



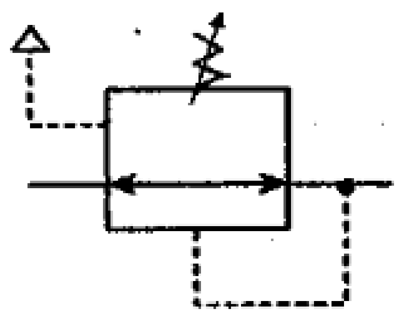
(a) Construction and operation

(b) Graphic symbol

Air Pressure Regulator

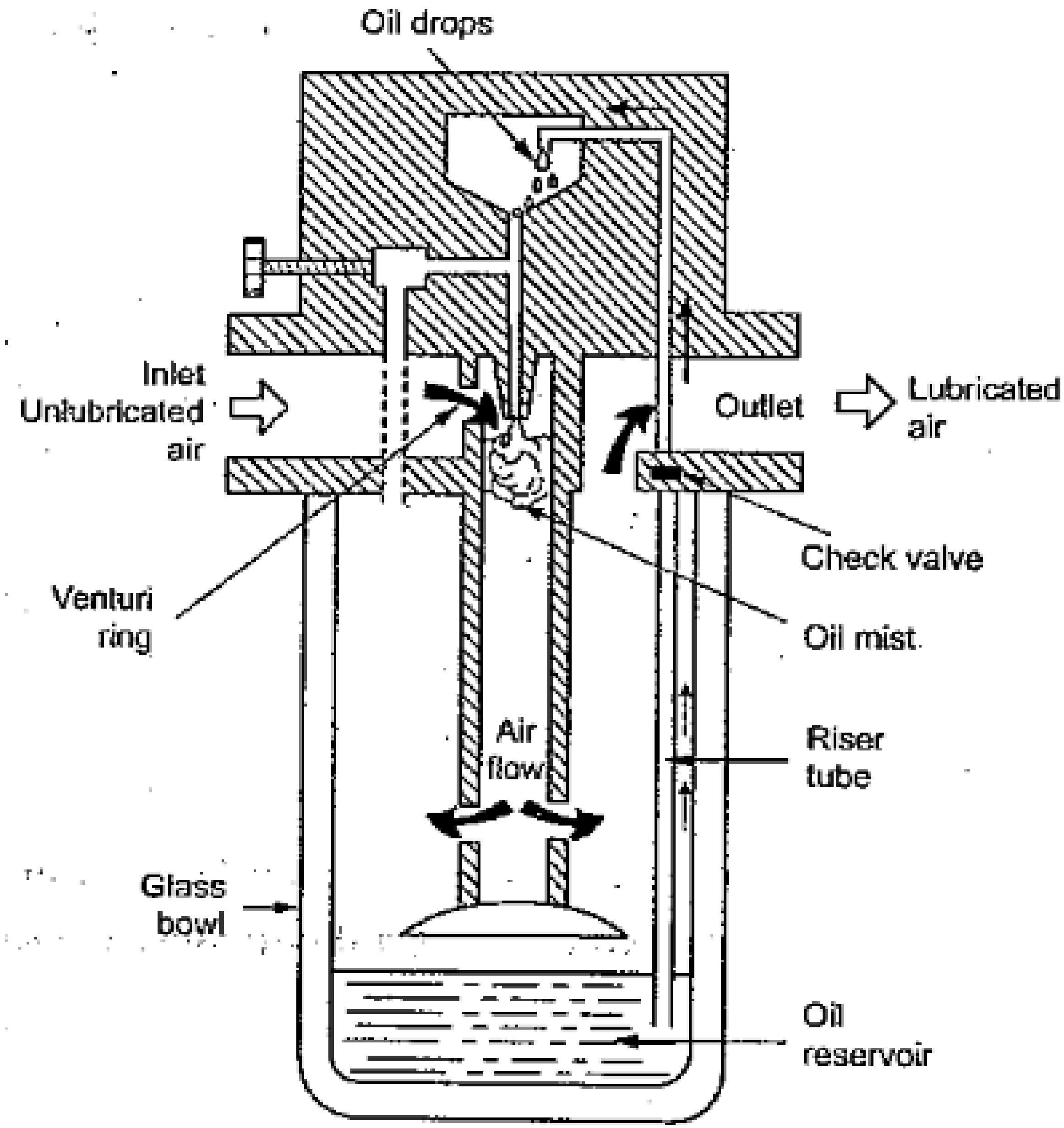


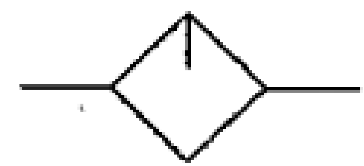
(a) Construction and operation



(b) Graphic symbol

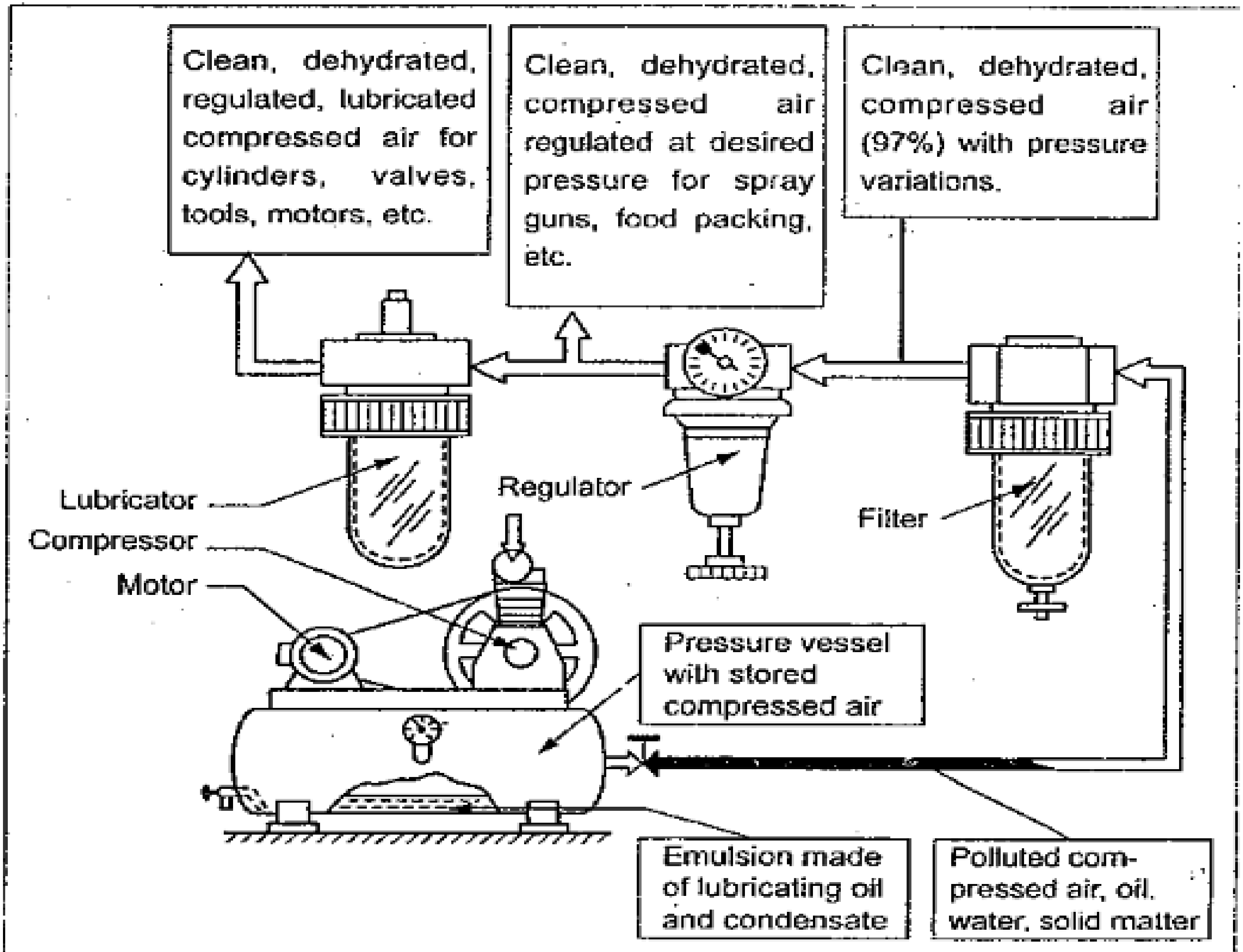
Air Lubricator



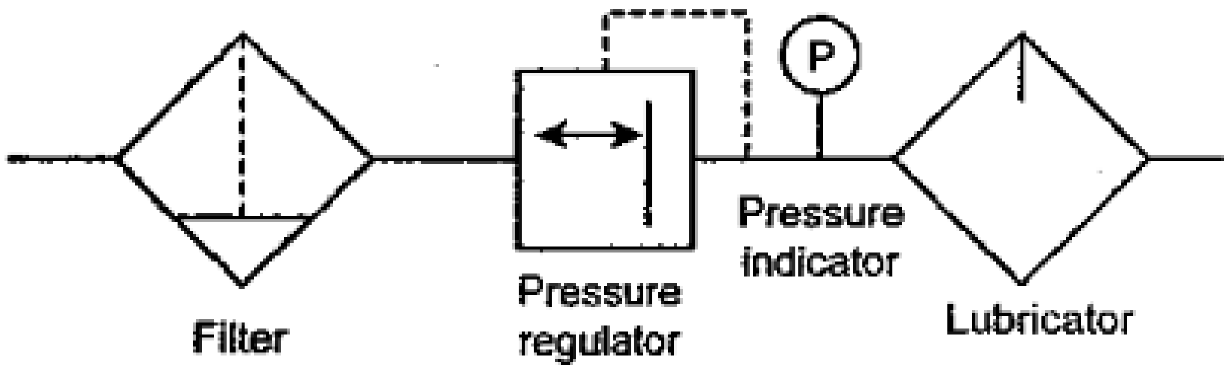


(b) Symbol for lubricator

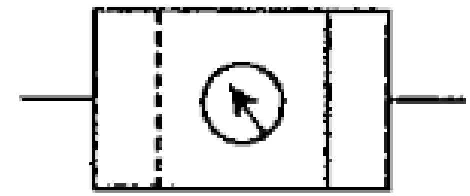
FRL Unit



Clean, dehydrated, regulated, lubricated compressed air for cylinders, valves, tools, motors, etc.
Clean, dehydrated, compressed air regulated at desired pressure for spray guns, food packing, etc.
Clean, dehydrated, compressed air (97%) with pressure variations.
Lubricator
Regulator
Filter
Compressor
Motor
Pressure vessel with stored compressed air
Emulsion made of lubricating oil and condensate
Polluted compressed air, oil, water, solid matter



(a) Graphic symbols for individual components



(b) Composite symbol

Pneumatic Valves and Actuators

Pneumatic Valves

The main functions of pneumatic valves are :

(*i*) To start and stop pneumatic energy;

(*ii*) To control the directional flow of compressed air;

(*iii*) To control the flow rate of the compressed air; and

(*iv*) To control the pressure rating of the compressed air.

Types of Pneumatic Valves

I. Classification based on their main function :

1. Directional control valves,

   (*i*) Check valves,

   (*ii*) Shuttle valves,

   (*iii*) Two-way D.C valves,

   (*iv*) Three-way D.C valves, and

   (*v*) Four-way D.C valves.

2. Pressure control valves, and

3. Flow control valves.

II. Classification based on their construction :

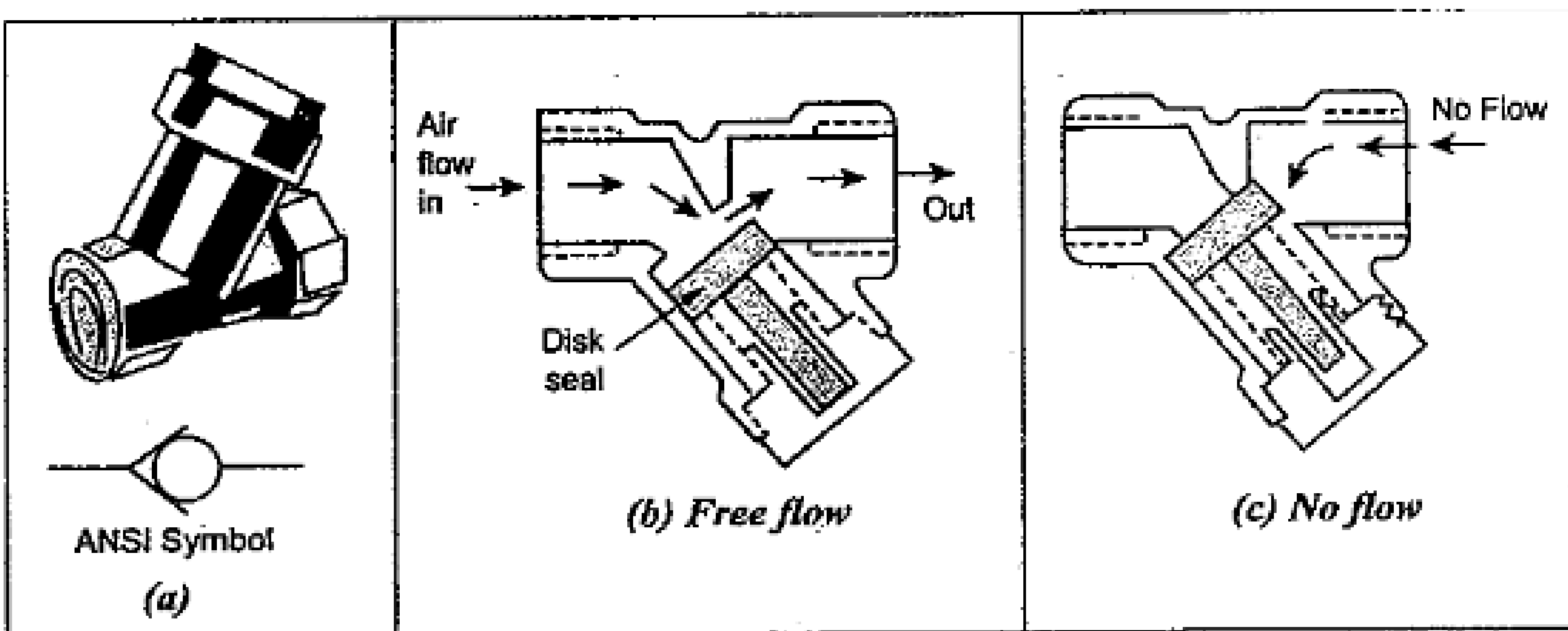
1. Poppet (or seat) type valve,

2. Sliding spool type valves, and

3. Rotary spool type valves.

Check Valves

- ✓ ***Functions :*** The check valves are used :
  - (*i*) to allow free flow of compressed air in only one direction, and
  - (*ii*) to prevent any flow of compressed air in the opposite direction.
- ✓ Since check valves block the reverse flow of the fluid, they are also known as ***non-return valves.***



ANSI Symbol

(a)

(b) Free flow

(c) No flow

Directional Control Valves

- ✓ As the name suggests, *the function of a directional control valve (DCV) is to control the direction of flow in a pneumatic circuit.*
- ✓ The DCVs are used to start, stop and regulate the direction of air flow and to help in the distribution of air in the desired line.

1. Based on the construction :

(*i*) Poppet (or seat) valves,

(*ii*) Sliding spool valves, and

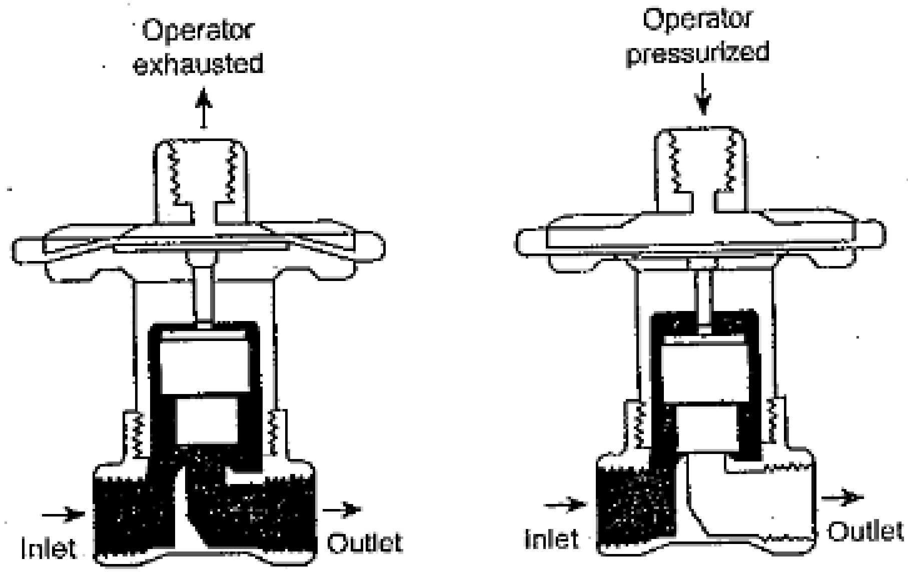
(*iii*) Rotary spool valves.

2. Based on the number of ports present :

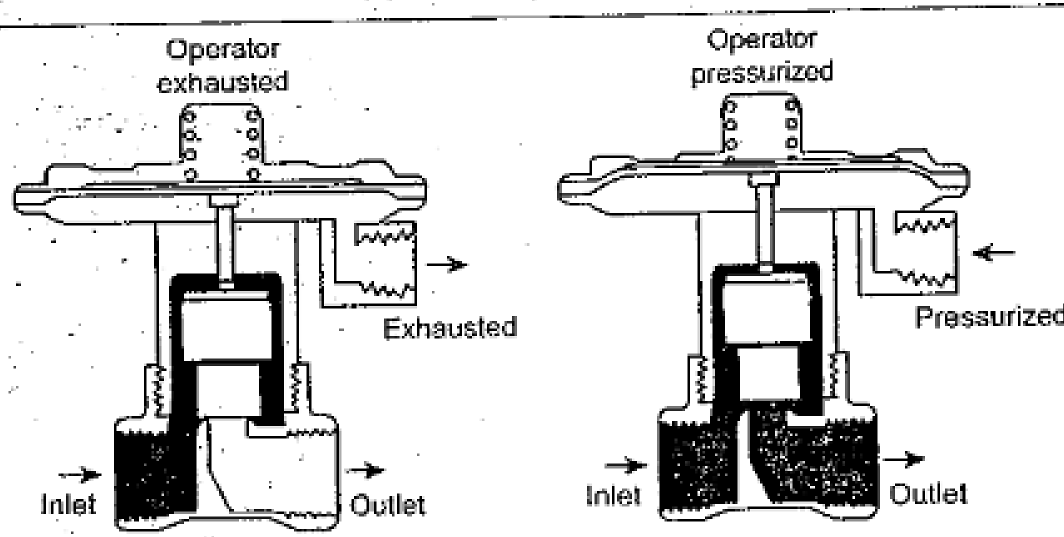
(*i*) Two way valves,

(*ii*) Three way valves, and

(*iii*) Four way valves.

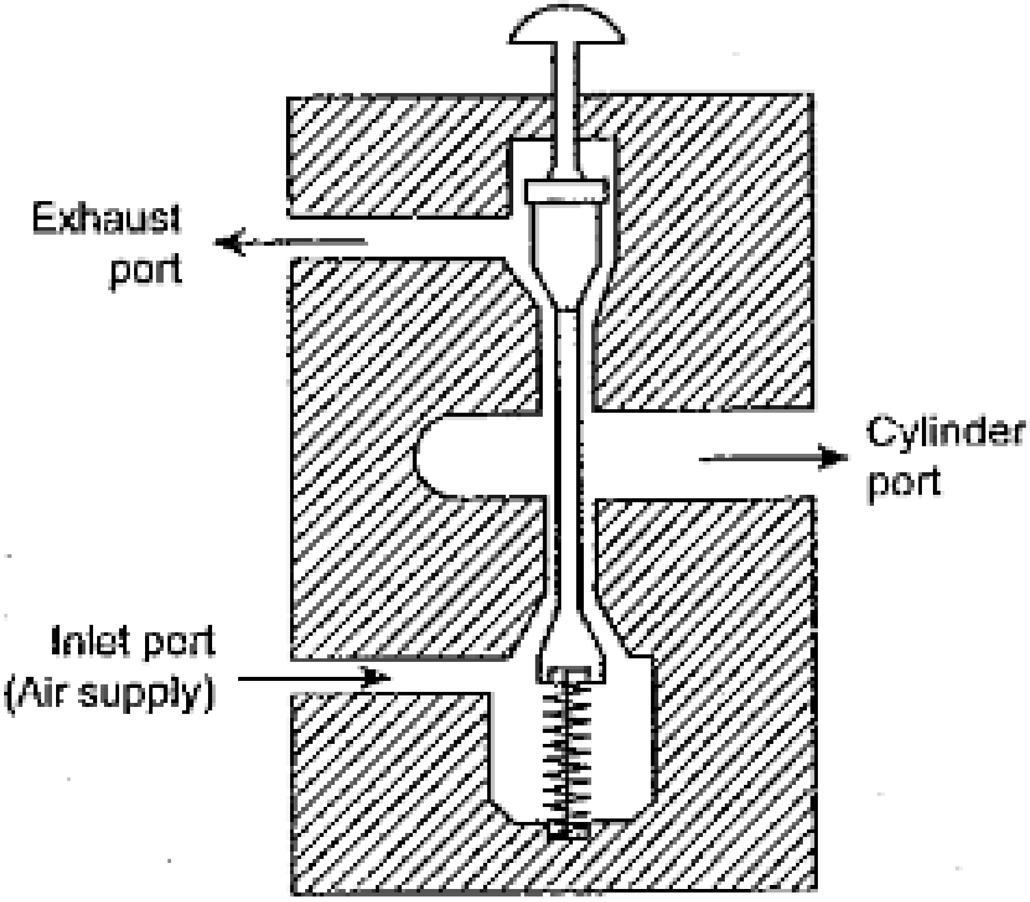


(a) Normally open

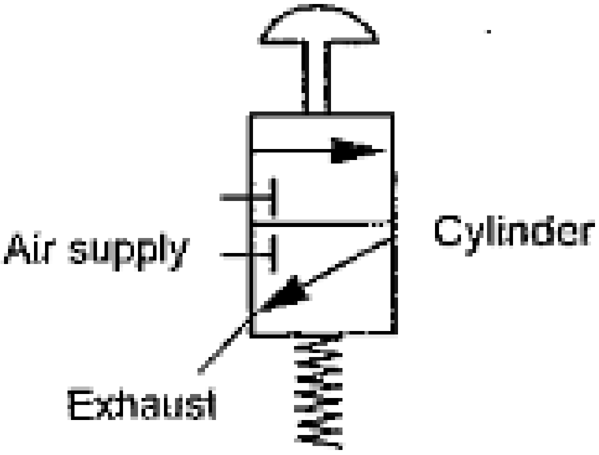


(b) Normally closed

Three-way valve (3/2 DCV)

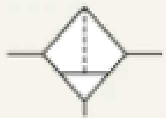
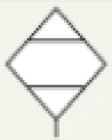
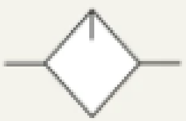
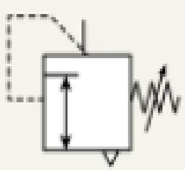
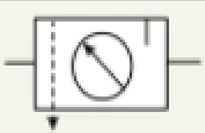


(a)

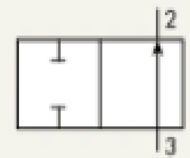
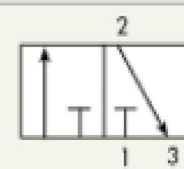
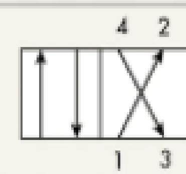
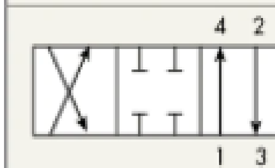
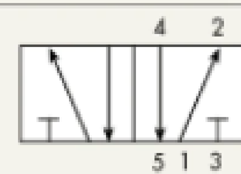


(b) Graphic symbol

SERVICE UNITS

Symbol	Designation	Explanation
	Air filter	This device is a combination of filter and water separator
	Dryer	For drying the air
	Lubricator	For lubrication of connected devices, small amount of oil is added to the air flowing through this device
	Regulator	To regulate the air pressure
	FRL unit	Combined filter, regulator and lubricator system

DIRECTION CONTROL VALVES (DCVs)

Symbol	Designation	Explanation
	2/2 way valve	Two closed ports in the closed neutral position and flow during actuated position
	3/2 way valve	In the first position flow takes place to the cylinder. In the second position flow takes out of the cylinder to the exhaust (Single acting cylinder)
	4/2 way valve	For double acting cylinder all the ports are open
	4/3 way valve	Two open positions and one closed neutral position
	5/2 way valve	Two open positions with two exhaust ports

Pneumatic Actuators

- ✓ *Pneumatic cylinders are the devices for converting the air pressure into linear mechanical force and motion.*
- ✓ The pneumatic cylinders are basically used for single-purpose applications such as clamping, stamping, transferring, branching, allocating, ejecting, metering, tilting, bending, turning and many other applications.

1. Based on the applications for which air cylinders are used :

(*i*) Light duty air cylinders,

(*ii*) Medium duty air cylinders, and

(*iii*) Heavy duty air cylinders.

2. Based on the cylinder action :

(*i*) Single-acting cylinders, and

(*ii*) Double-acting cylinders.

3. Based on the cylinder's movement :

(*i*) Rotating type air cylinders, and

(*ii*) Non-rotating type air cylinders.

4. Based on the cylinder's design :

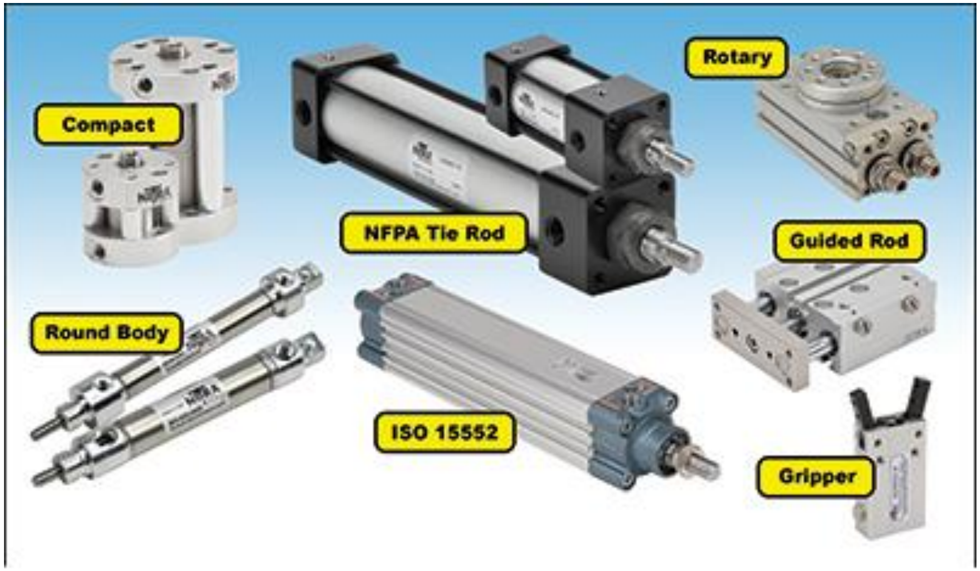
(*i*) Through rod cylinders,

(*ii*) Cushion end cylinders,

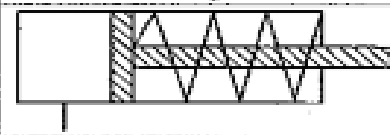
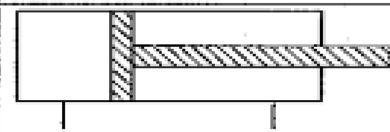
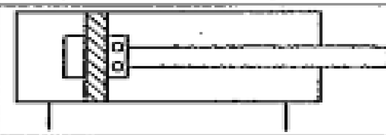
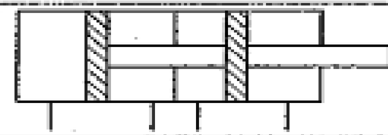
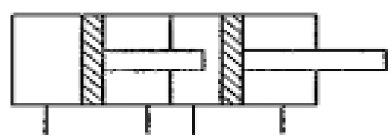
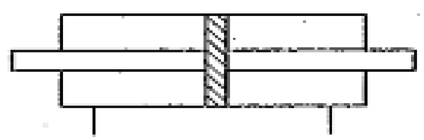
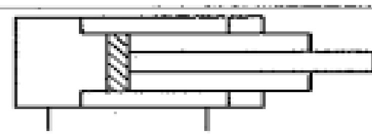
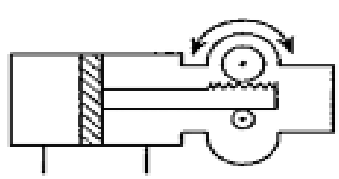
(*iii*) Tandem cylinders,

(*iv*) Double rod cylinders,

(*v*) Telescoping cylinders, *etc.*



Pneumatic Actuators

Sl.No.	Cylinder Type	Diagram	Description
1.	Single-acting cylinder		Air pushes the piston in one direction and the piston is returned by means of an external spring.
2.	Double-acting cylinder		The force exerted by the compressed air moves the piston in both directions.
3.	Cushion end cylinder		Cushioning is used in the end positions to prevent sudden damaging impacts.
4.	Tandem cylinder		Here two cylinders are arranged in series so that the force obtained from the cylinder is almost doubled.
5.	Dual linear cylinder (Three position cylinder)		Similar to tandem cylinder, but the piston and rod assemblies of a dual actuator are not fastened together as in the tandem cylinder.
6.	Double-rod cylinder (Through rod cylinder)		It has piston rods extending from both ends of the cylinder. It produces equal force and speed on both sides of the cylinder.
7.	Telescoping cylinder		It is a two-stage, double-acting telescopic cylinder; for more details refer Section 6.6.2.
8.	Turn cylinder (Rotary cylinder)		It has a piston rod having rack and pinion arrangement in such a manner that with linear movement of the piston rod, the worm wheel rotates at 45°, 90°, 180°, *etc.*

Fluid Power Circuits Design

Pneumatic Circuits

✓ *A pneumatic circuit may be defined as the graphic representation of the pneumatic components in a pneumatically operated machine.*

✓ *The four important factors that should be considered while designing any fluid power circuit are :*

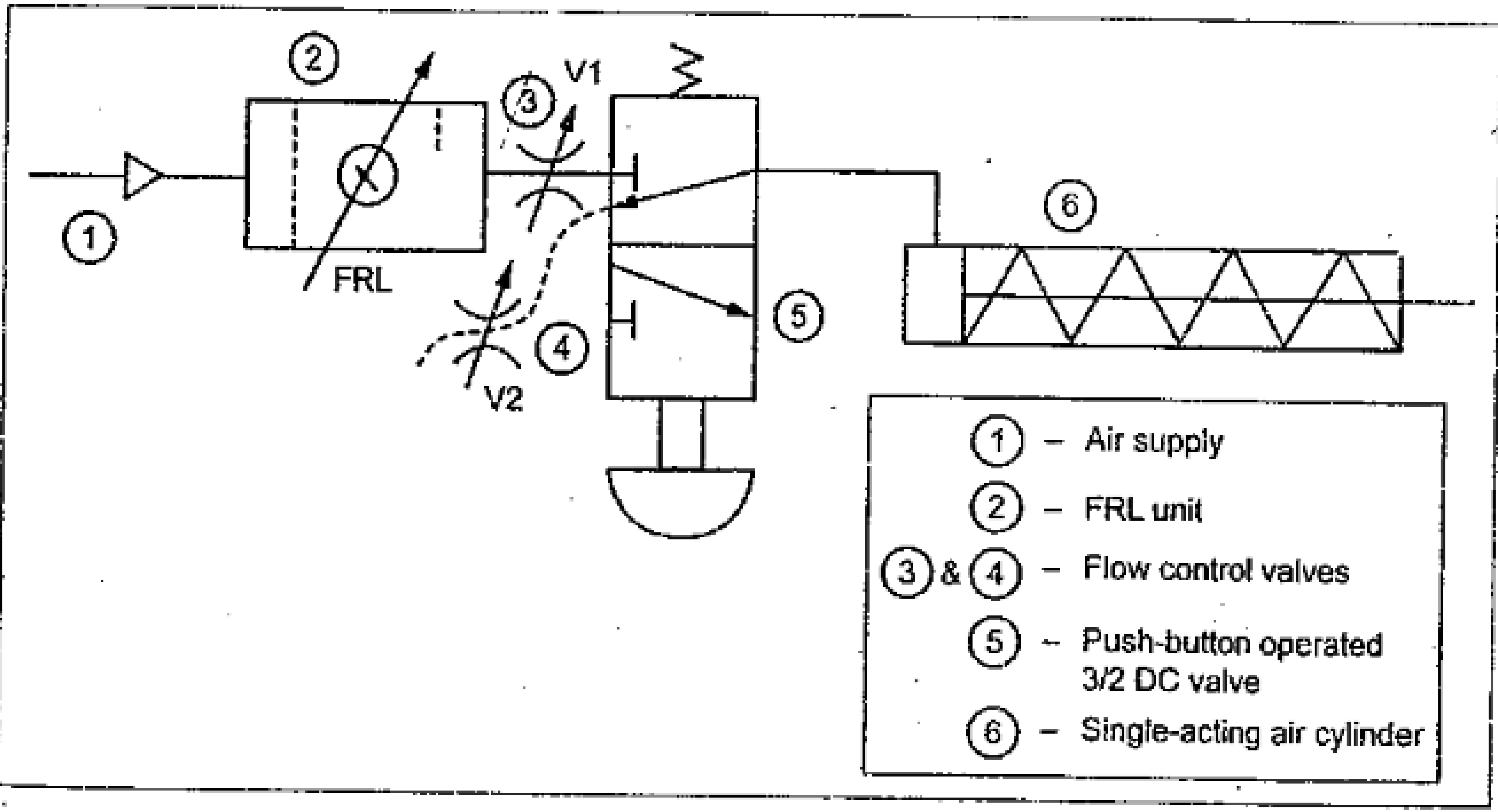
(i) *Safety of operation,*

(ii) *Performance of desired function,*

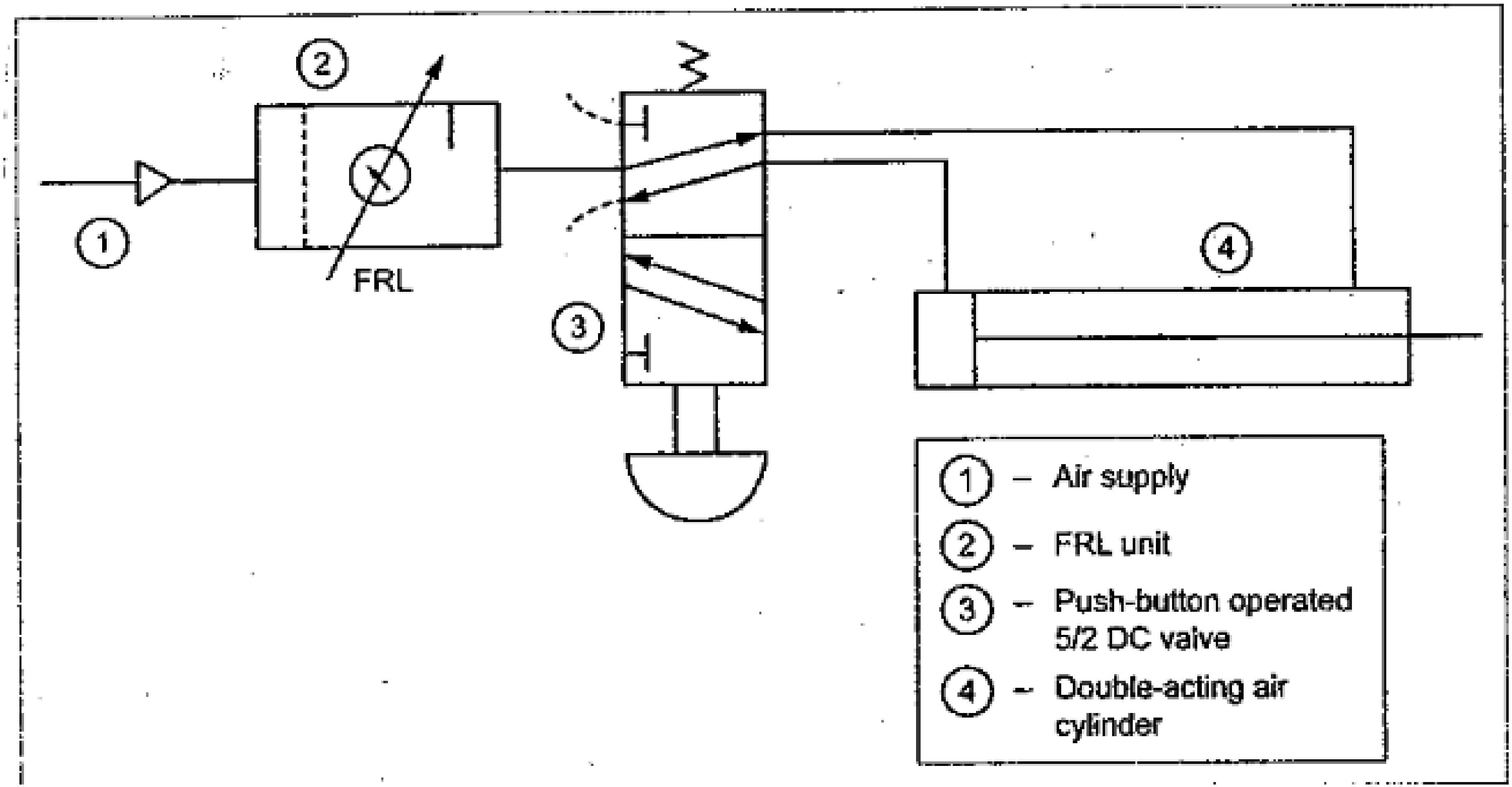
(iii) *Efficiency of operation, and*

(iv) *Cost.*

1. Control of Single acting Cylinder Pneumatic Cylinder

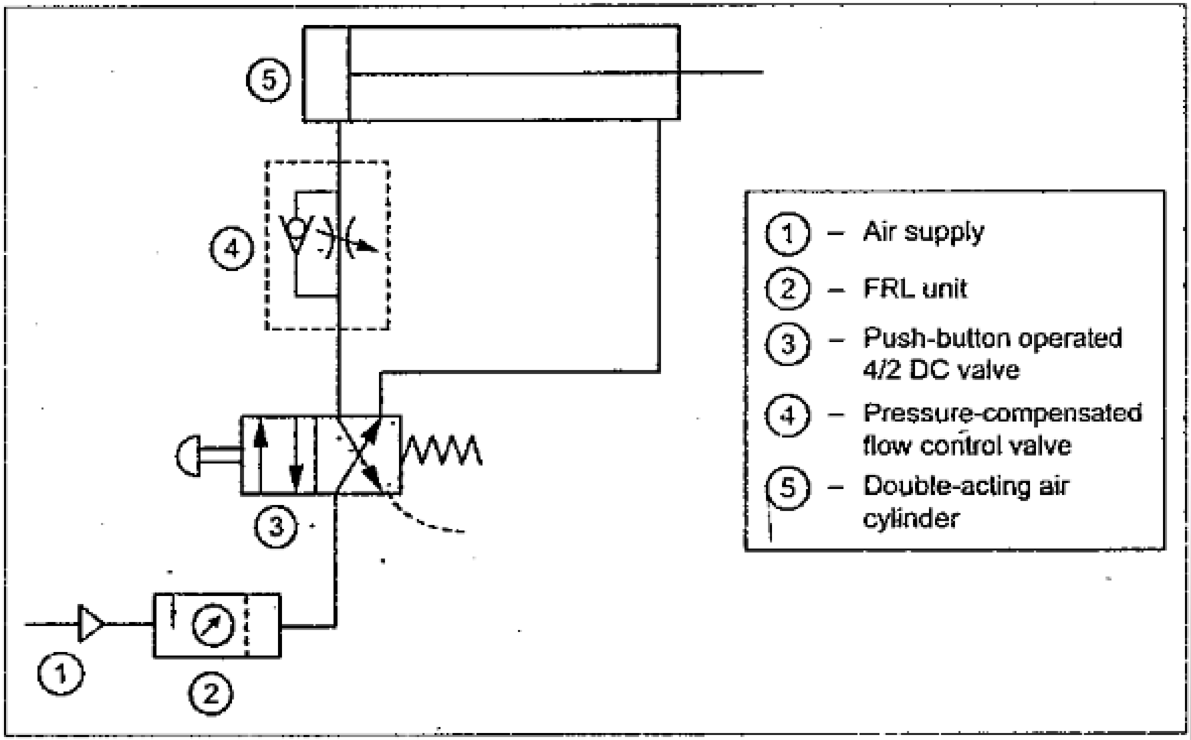


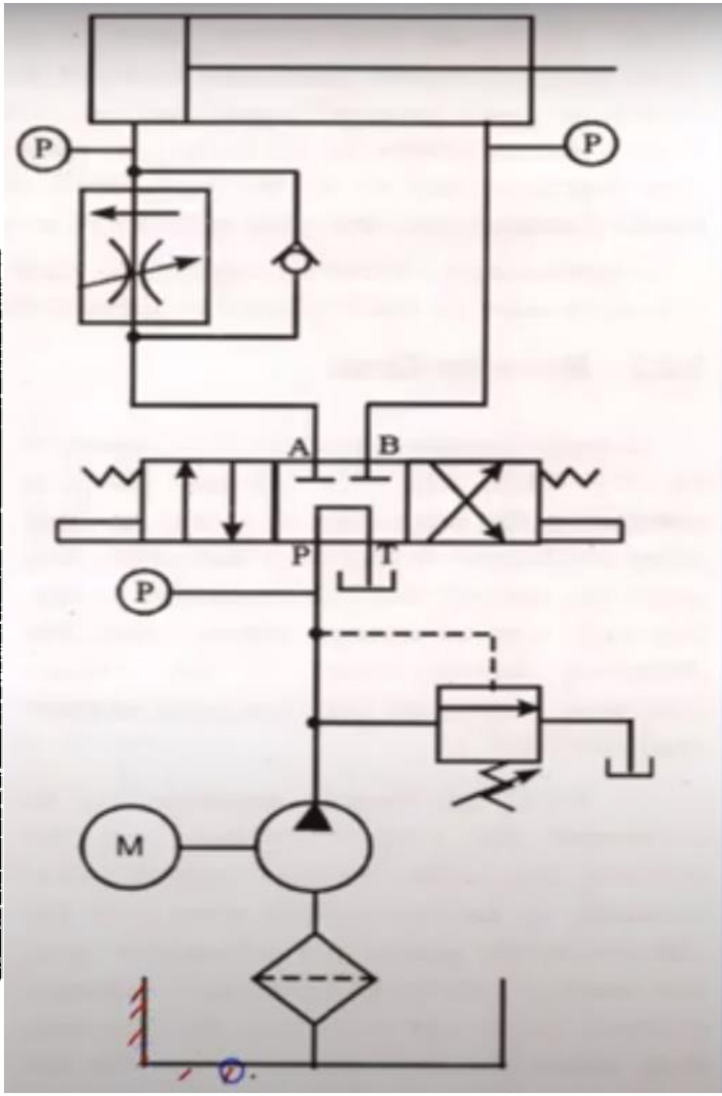
2. Control of Double acting Cylinder Pneumatic Cylinder



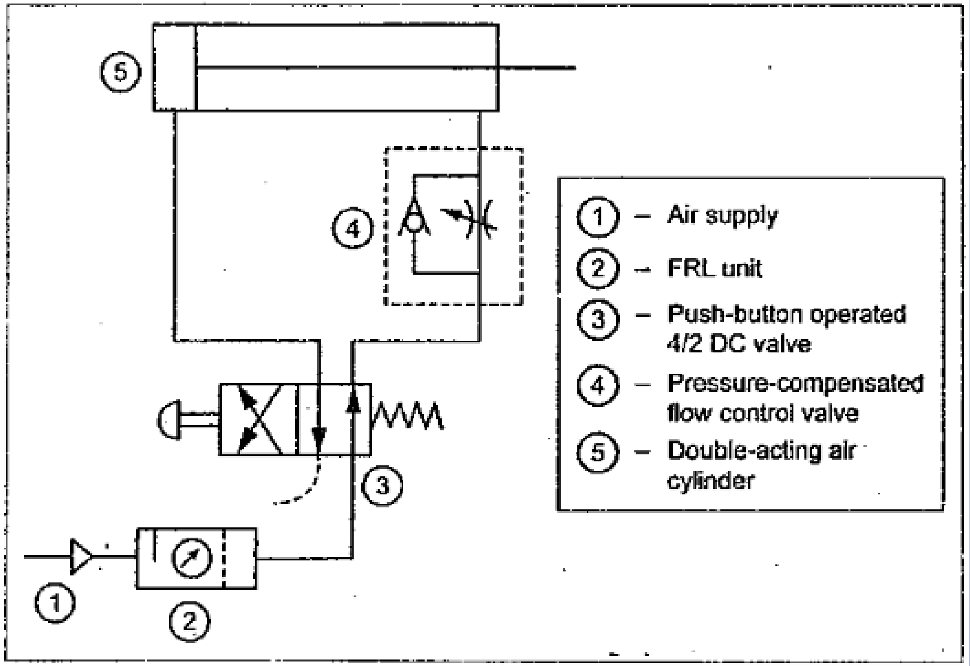
3. Speed Control circuit for Pneumatic Cylinder

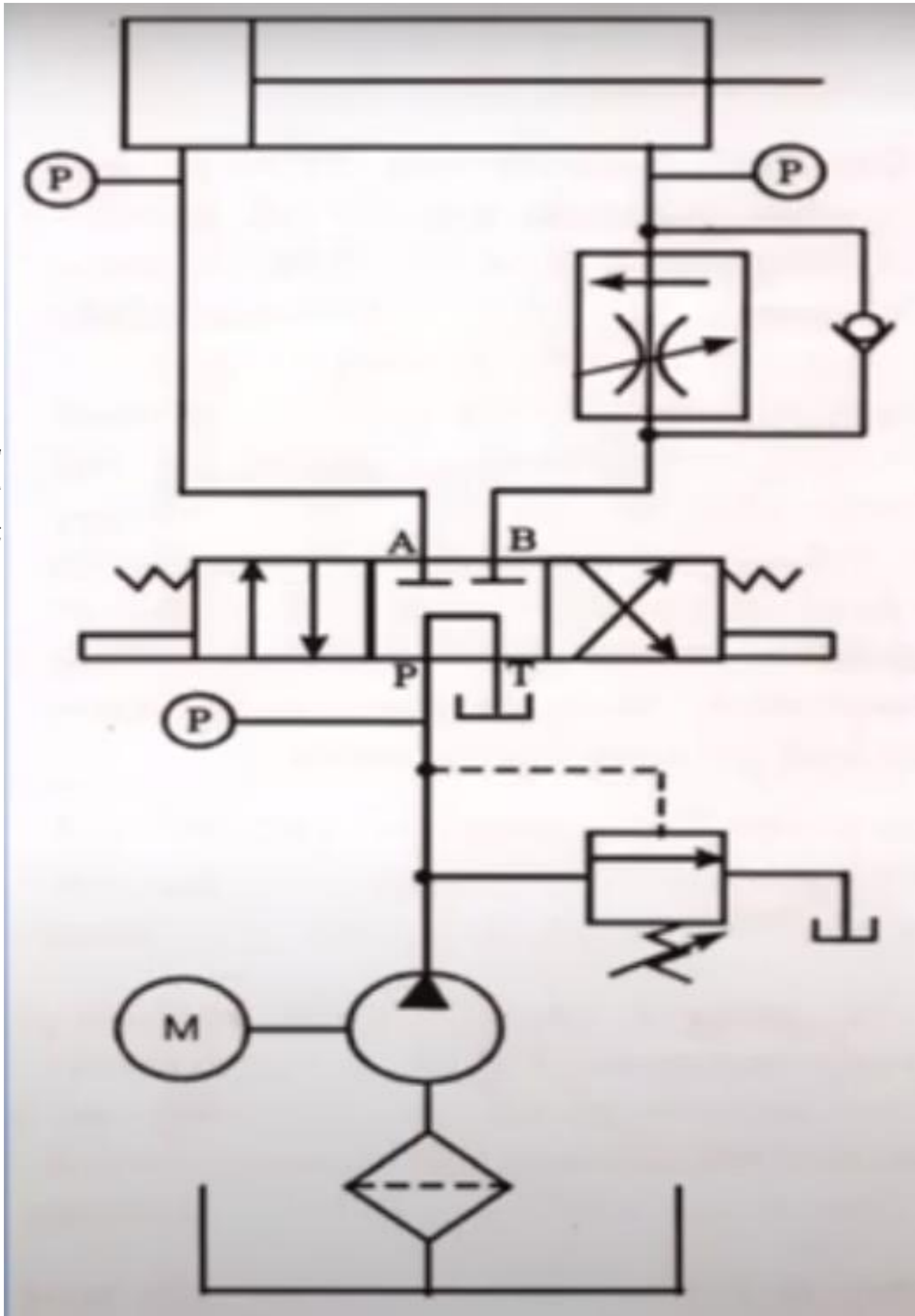
a) Metter-in circuit





b) Metter-out circuit





Pneumatic Logic Circuits

In the preceding sections, we have discussed few basic pneumatic circuits. It should be noted that a pneumatic circuit for a particular application can be designed in various methods. The five methods commonly used by engineers are :

1. Cascade method,
2. Classic or intuitive method,
3. Step-counter method,
4. Karnaugh-Veitch (K-V) mapping method, and
5. Combinational circuit design.

Casecade Method of Pneumatic Circuit Design

Procedure

Step1 : Each cylinders are given, for convenience, individual letters (say A, B, C, *etc.*). The given sequence is written first with '+' representing extension (forward) stroke of the cylinder and '–' representing retraction (return) stroke of the cylinder. (For example A^+, B^+, A^-, B^-, *etc.*)

Step 2 : The given sequence is split into minimum number of groups. The grouping can be done as below :

(*i*) The first group is split where the change in stroke occurs.

(*ii*) The second, third and subsequent groups are formed such that maximum of one change occurs within the group.

(*iii*) No letter should be repeated within any group.

(*iv*) The groups are identified by letters like I, II, III, *etc.*

Illustration : Let us assume the sequence A^+ B^+ B^- C^+ C^- A^-. This sequence can be splitted into three groups as shown below :

$$\frac{A^+\,B^+}{I},\ \frac{B^-\,C^+}{II},\ \frac{C^-\,A^-}{III}$$

Step 3 : Each group is assigned a pressure manifold line which must be pressurised only during the time the particular group is active.

∴ *Number of pressure lines = Number of groups*

Step 4 : Selection of valves :

(*i*) Each cylinder is provided with a pilot operated 4/2 DC valve.

∴ *Number of pilot control valves = Number of cylinders*

(*ii*) Limit valves are positioned at either end actuated by the piston rod to identify the extension and retraction of cylinders. The limit valves are denoted by a_0, a_1, b_0, b_1, *etc.*, where the suffix '0' corresponds to valves which are actuated at the end of return stroke and the suffix '1' corresponds to valves which are actuated at the end of forward stroke. Each cylinder requires two limit valves.

∴ *Number of limit valves = 2 × Number of cylinders*

Each manifold line supplies air pressure to those limit valves within its particular group.

(*iii*) In order to pressurize the various manifold lines in the proper order, one or more group changing valves or cascade valves are used.

∴ *Number of cascade (or group changing) valves = Number of groups – 1*

Step 5 : The valve connections are made as follows :

(*i*) The output of each limit valve is connected to the pilot input corresponding to the next sequence step.

(*ii*) The limit valve corresponding to the last step of the given group is 'not' connected to the pilot actuation of the DC valve of next cylinder. Instead, it is connected to the pilot line of the group changing or cascade valve so as to pressurize the manifold of the subsequent group.

This manifold line is then connected to the pilot line corresponding to the first step of the next group.

Advantages

1. Circuit design, drawing and checking can be accomplished very quickly.
2. Fault diagnosis and trouble-shooting are very simple.
3. Required task by each cylinder and their signal elements is fully ensured.
4. This avoids a problem that may occur because of air becoming trapped in the pressure line to control a valve and so preventing the valve from switching.

Grouping-Example

#1: A+ B+ C- C+ B- A –

A+ B+ C- | C+ B- A –

Group – I | Group – II

#2: A+ B+ B- C+ A- C-

A+ B+ | B- C+ A- | C- *(Moving the last alphabet to first)*

C- A+ B+ | B- C+ A-

Group – I | Group – II

#3: A+ A- B+ C- B- C+

A+ | A- B+ C- | B- C+ *(Moving the first alphabet to last)*

A- B+ C- | B- C+ A-

Group – I | Group – II

#4: A+ B+ B- C+ C- A-

A+ B+ | B- C+ | C- A- *(Not Possible to combine it as 2 groups)*

1. **No alphabet should be repeated with in the group.**
2. **The number of group should be minimum.** *This is possible by combining the groups without* ***violating the # rule one.***

Example 13.2 ***Three pneumatic cylinders A, B, and C are used in an automatic sequence of operation. A cylinder extends, B cylinder extends, B cylinder retracts and then A cylinder retracts, C cylinder extends and C cylinder retracts. Develop pneumatic circuits by cascade method.***

Step 1 : Given sequence is $A^+ \ B^+ \ B^- \ A^- \ C^+ \ C^-$

Step 2 : The given sequence can be initially splitted into three groups as

$$\underset{I}{\underline{A^+ \ B^+}}, \ \underset{II}{\underline{B^- \ A^- \ C^+}}, \ \underset{III}{\underline{C^-}}$$

In order to keep the number of groups minimal, the C^- can be assigned to group I. So the ideal grouping is as follows :

$$\underset{I}{\underline{C^- \ A^+ \ B^+}}, \ \underset{II}{\underline{B^- \ A^- \ C^+}}$$

Step 3 : Number of pressure lines = Number of groups = 2

Step 4 : Selection of valves :

(*i*) Number of pilot operated 4/2 DC valve = Number of cylinders = 3

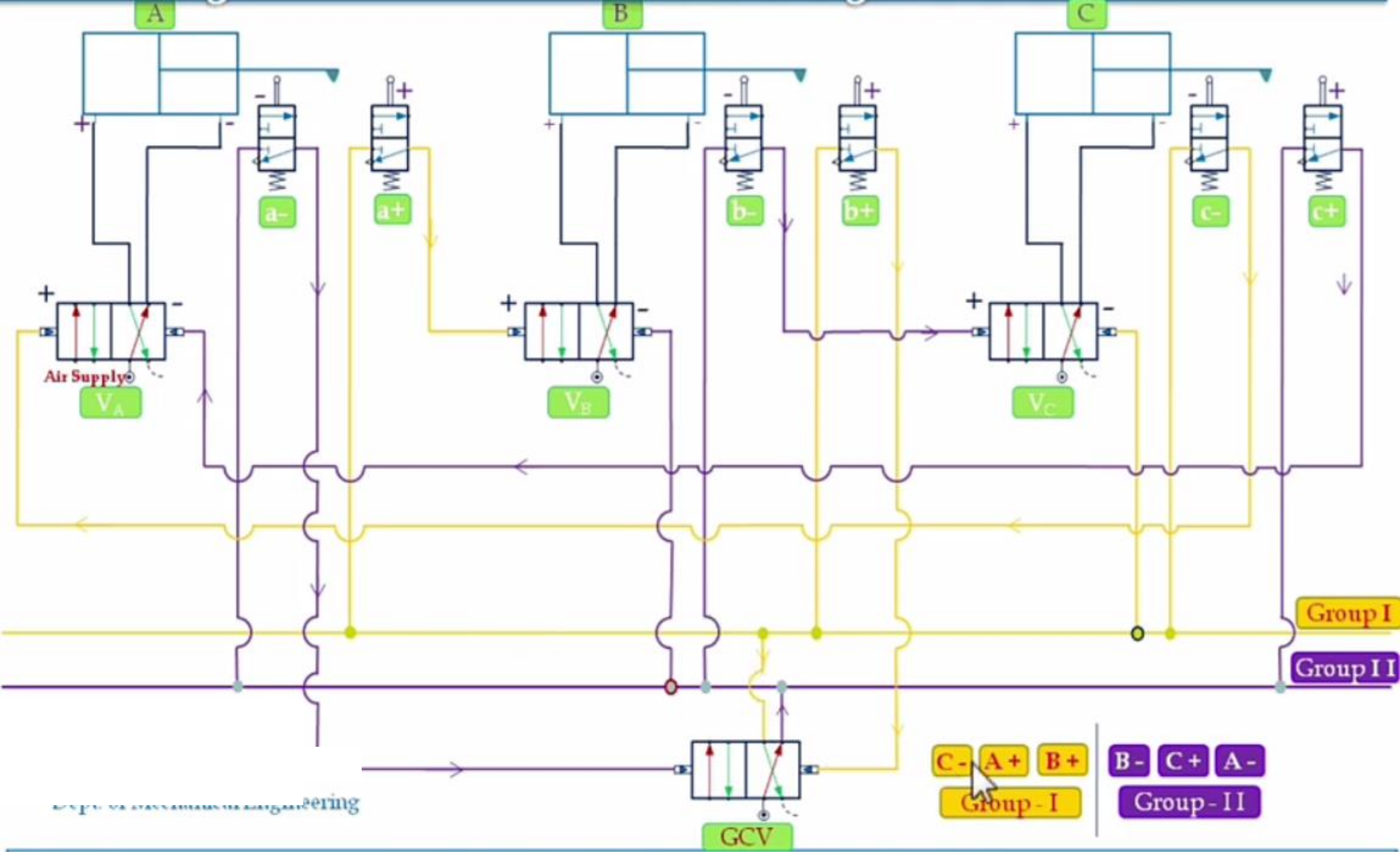
Thus three cylinder actuation—VA, VB, VC—are provided.

(*ii*) Number of limit valves = 2 × Number of cylinders = 2 × 3 = 6

Thus six limit valves—a_0, a_1, b_0, b_1, c_0, c_1—are provided.

(*iii*) Number of cascade (or group changing) valves $= \begin{Bmatrix} \text{Number of} \\ \text{groups} \end{Bmatrix} - 1 = 2 - 1 = 1.$

So for this circuit, only one cascade valve is sufficient.



A, B, C → *Double acting Cylinders*

a+, a-, b+, b-, c+, c- → *Limit valves to indicate end of strokes.*

V_A, V_B, V_C → *Pilot-operated 4/2 DCV*

GCV → *Group Changing Valve/Cascade Valve*

Group – I & II → *Pressure manifold lines*

Example 13.3 ***Develop an electropneumatic circuit by cascade method for the following sequence : $A^+B^+B^-A^-$ where A and B stand for cylinders, (+) indicates extension and (–) retraction of cylinders.***

Step 1 : Given sequence : $A^+ B^+ B^- A^-$

Step 2 : Grouping : $\frac{A^+ B^+}{I}, \frac{B^- A^-}{II}$

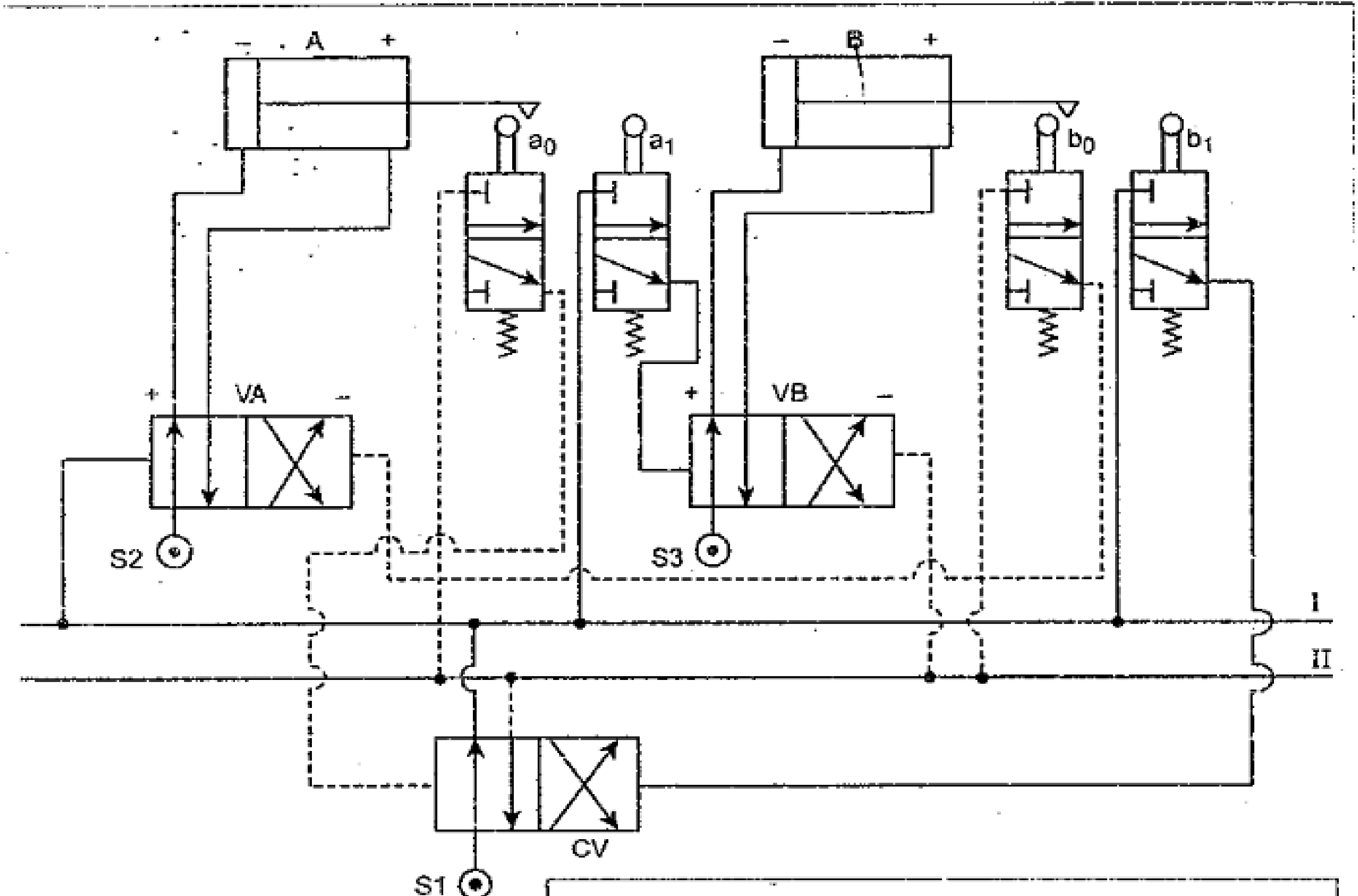
Step 3 : Number of pressure lines = Number of groups = 2

Step 4 : (*i*) Number of pilot operated 4/2 DC valve = Number of cylinders = 2

(*ii*) Number of limit valves = 2 × Number of cylinders = 2 × 2 = 4

(*iii*) Number of cascade valves = Number of groups – 1 = 2 – 1 = 1

Step 5 : The cascade circuit and their valve connections for the sequence $A^+ B^+ B^- A^-$ is drawn as shown in Fig.13.23.



——— represents operations of group I

- - - - - represents operatoins of group II

A, B – Double-acting pneumatic cylinders

CV – Cascade valve

VA and VB – 4/2 directional control valves for the cylinders A and B respectively.

a_0 and a_1 – Limit valves for cylinder A

b_0 and b_1 – Limit valves for cylinder B

S1, S2, S3 – Air supply