HYDRAULICS AND PNEUMATICS

UNIT - 1
INTRODUCTION TO HYDRAULIC POWER

- *WHAT IS HYDRAULIC SYSTEM?*

- *Hydraulic system is the technology that deals with the generation, control, and transmission of power, using pressurized liquid.*

- *The word hydraulics is derived from the Greek word HYDRO and means Water.*

ADVANTAGES OF HYDRAULIC SYSTEM

1. Easy and accuracy of control(by the use of simple lever and push button)
2. Multiplication of force(without using cumbersome gears, pulleys and levers)
3. Constant force or torque(regardless of speed changes)
4. Simplicity, safety, economy(fewer moving parts compare to mechanical or electrical system)

5. High force density and compact construction
6. Long life cycle and low maintenance
7. Easily automated
8. Easy reversal movement.

LIMITATIONS OF HYDRAULIC SYSTEM

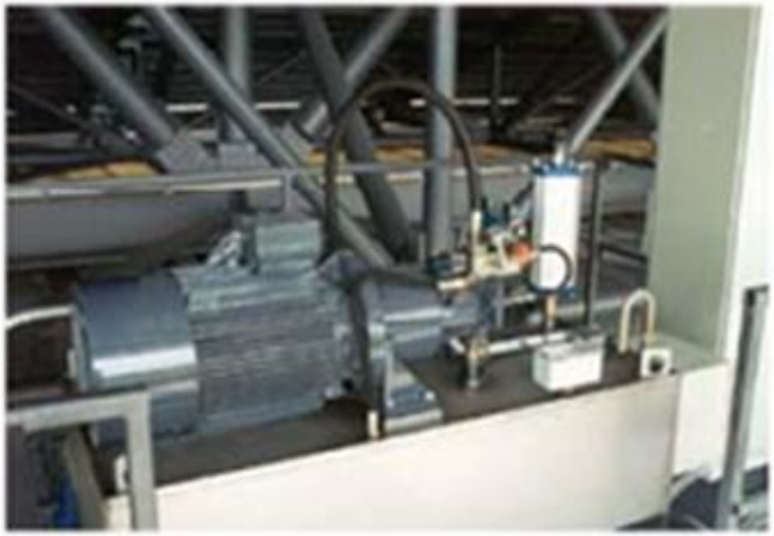
- Hydraulic lines are messy , and leakage is impossible to eliminate completely.
- Hydraulic lines can burst, possibly resulting in injuries to people.
- Most hydraulic oils can cause fires if an oil leak occurs in an area of hot equipment.
- Hydraulic oil always should be clean filtration is very critical

Advantages

- High force density, compact construction
- Easy reversal of movement
- Good controllability
- Easy movement conversion
- Simple overload protection
- Design flexibility, force transfer over long distance
- Long life cycle, low maintenance
- Extensive standardization, interchangeable
- Easily automated

Limitations

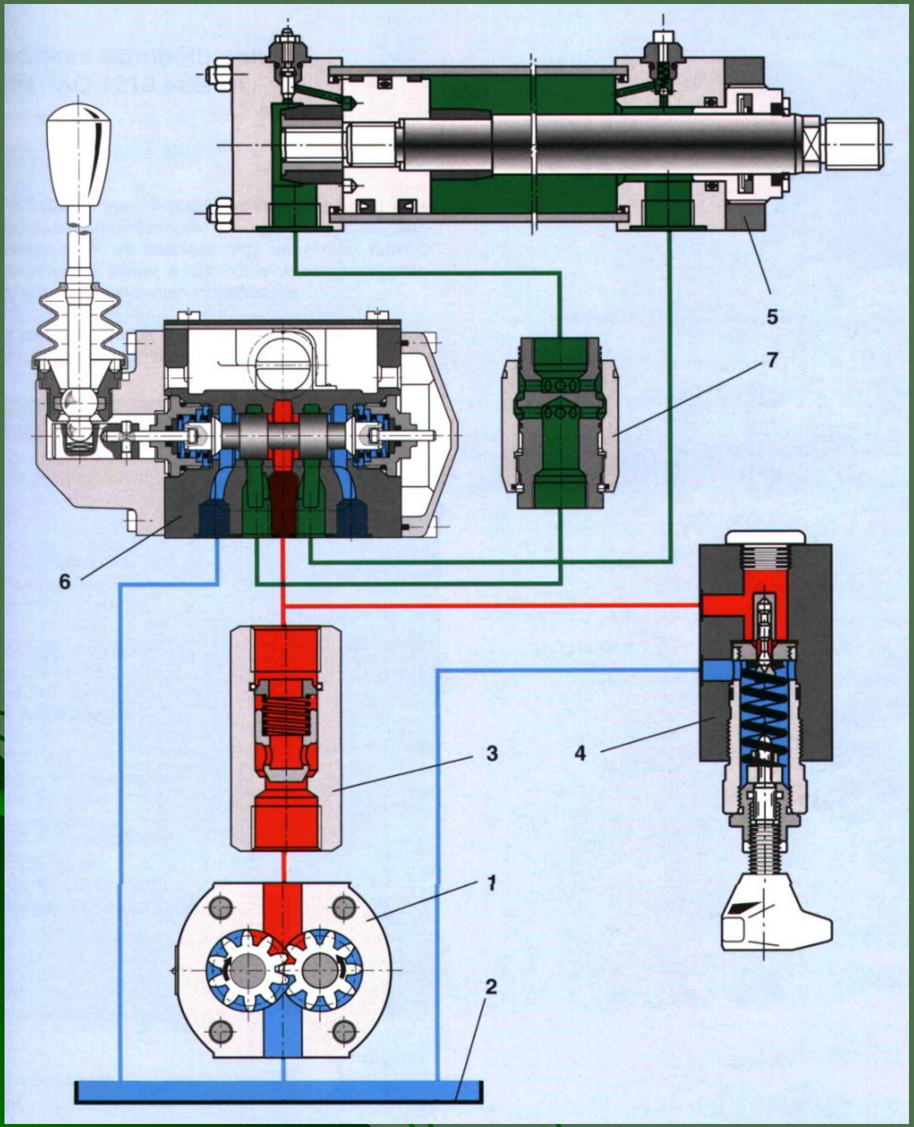
- Temperature dependency
- Leakage problems
- Compressibility
- Manufacturing costs

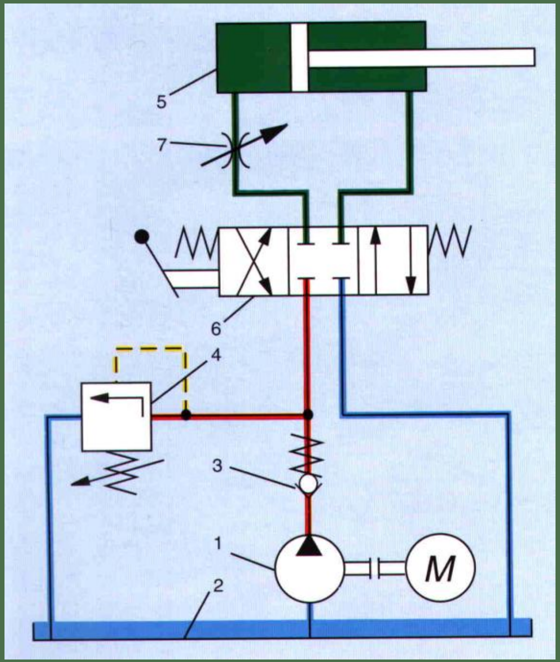


COMPONENTS OF A HYDRAULIC SYSTEM

1. A tank (reservoir) to hold the hydraulic oil.
2. A pump to force the oil through the system.
3. An electric motor or other power source to drive the pump.
4. Valves to control oil direction, pressure, and flow rate.
5. An actuator to convert the pressure of the oil into mechanical force or torque to do useful work.
6. Piping which carries the oil from one location to another.

Components of a simple hydraulic system





1 – pump

2 – oil tank

3 – flow control valve

4 – pressure relief valve

5 – hydraulic cylinder

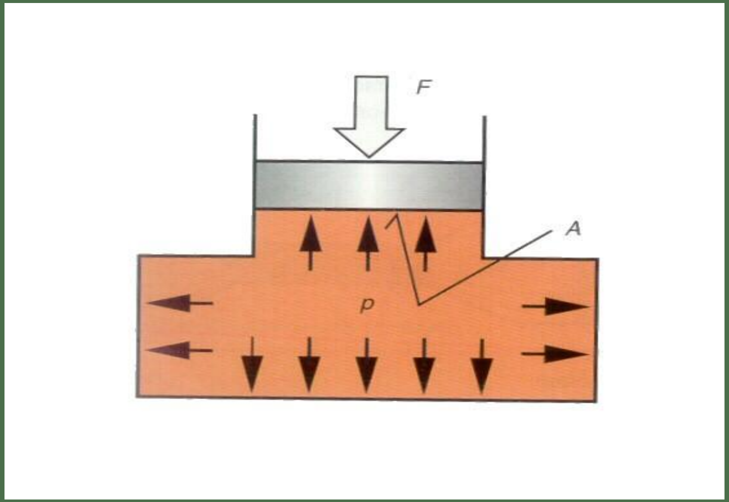
6 – directional control valve

7 – throttle valve

Applications of hydraulic system

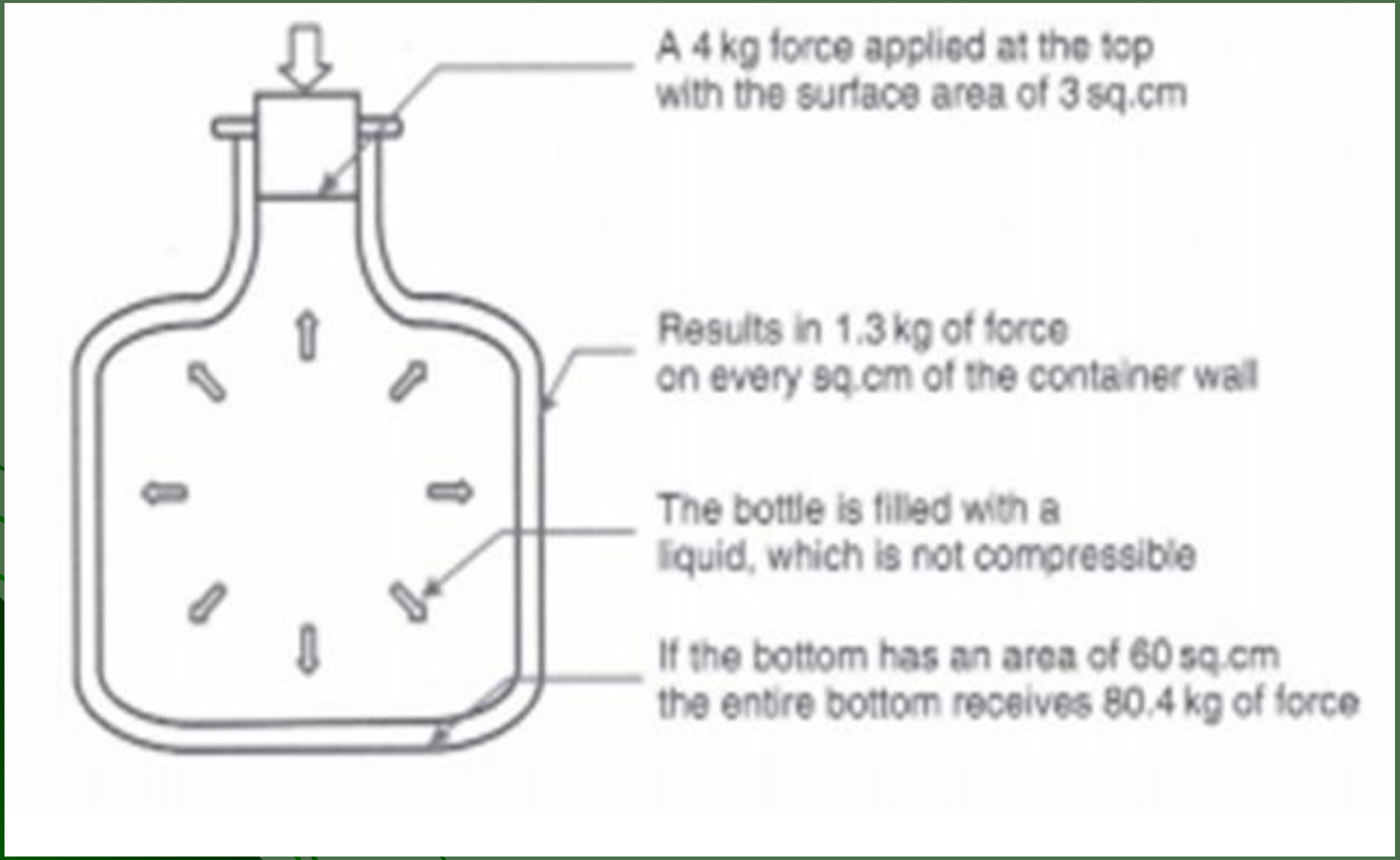
1. It jacks up an automobile (Hydraulic jack)
2. Drives high over head trams
3. Launches space ship
4. Control submarines
5. Coal mines
6. Moves earth (Earth moving equipment like excavators, bull dozers, borewell drills etc.,)
7. Harvest crops
8. Presses
9. Machine tools
10. Material handling equipment
11. Transportation
12. Construction

PASCAL'S LAW



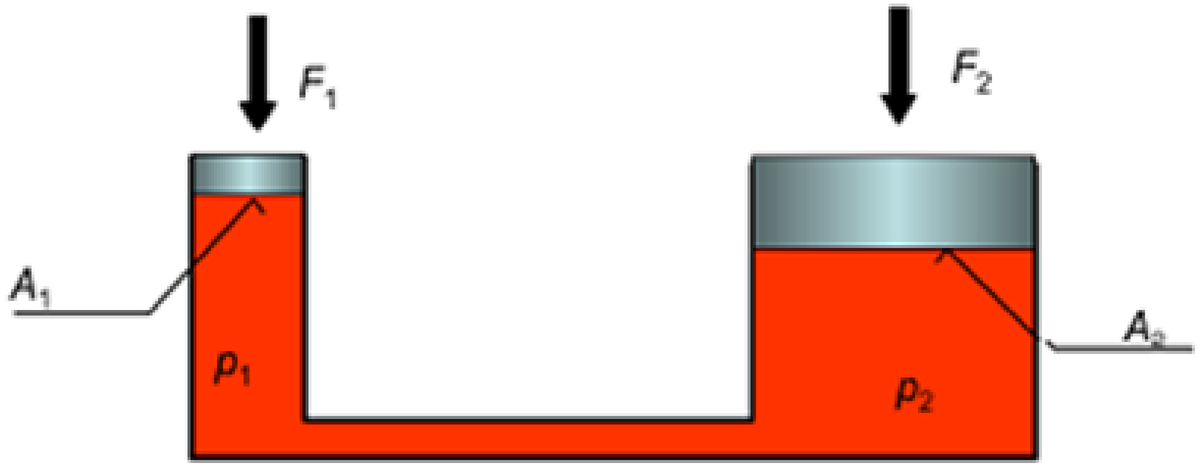
Fluid power technology actually began in 1650 with the discovery of Pascal's Law. Simply this law says that:
"Pressure applied to a confined(static) fluid is transmitted undiminished in all directions throughout the fluid and acts perpendicular to the surfaces in contact with the fluid."

Application of Pascal's law to simple hydraulic jack (Force multiplication)



Basic Physical Principles I Pascal's Law

Application : Force Transmission



$p_1 = \frac{F_1}{A_1}$ $p_2 = \frac{F_2}{A_2}$

At equilibrium: $p_1 = p_2$ or $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ ⇨ $\frac{F_1}{F_2} = \frac{A_1}{A_2}$

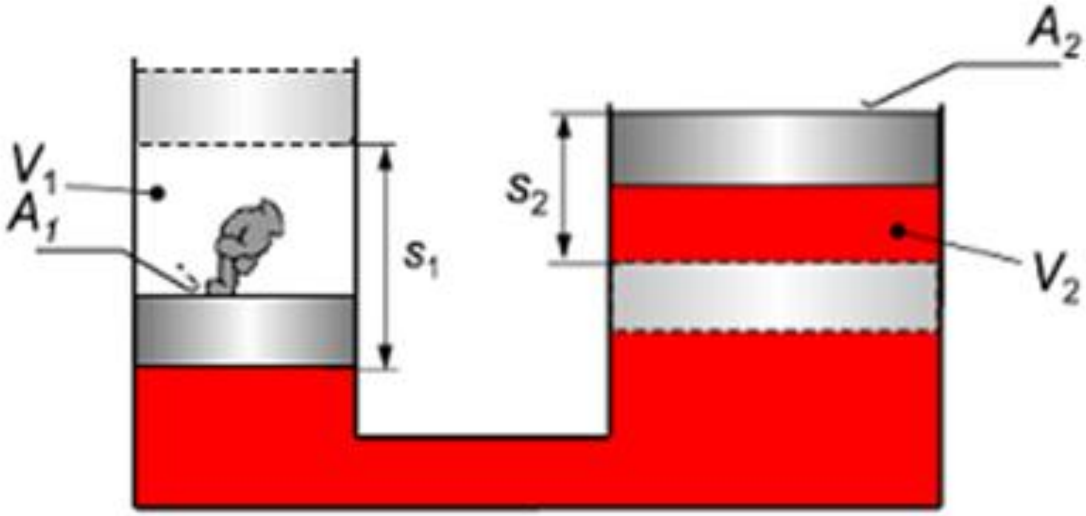
Basic Physical Principles I Pascal's Law

Sample Calculation: Displacement Transmission

$V_1 = V_2$

$V_1 = A_1 \cdot s_1$

$V_2 = A_2 \cdot s_2$



V = volume (displaced) in cm^3

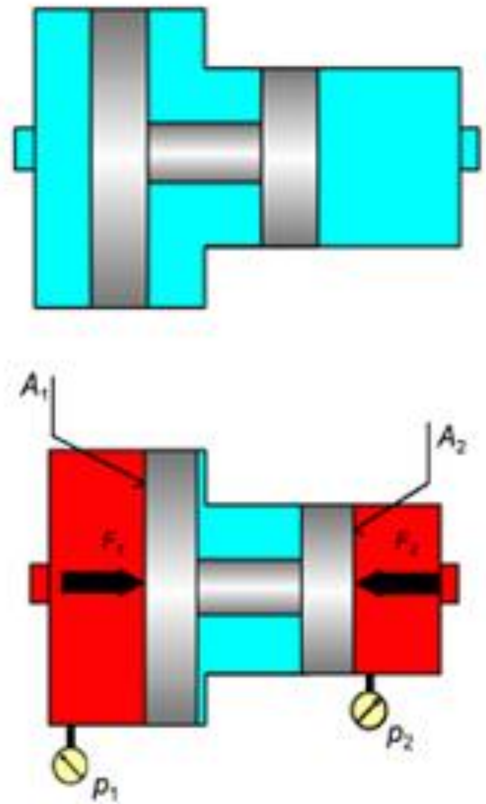
S = Piston displacement in cm

A = Area in cm^2

At equilibrium: $V_1 = V_2$ or $A_1 \cdot s_1 = A_2 \cdot s_2$ ⇨ $\frac{s_1}{s_2} = \frac{A_2}{A_1}$

Basic Physical Principles I Pascal's Law

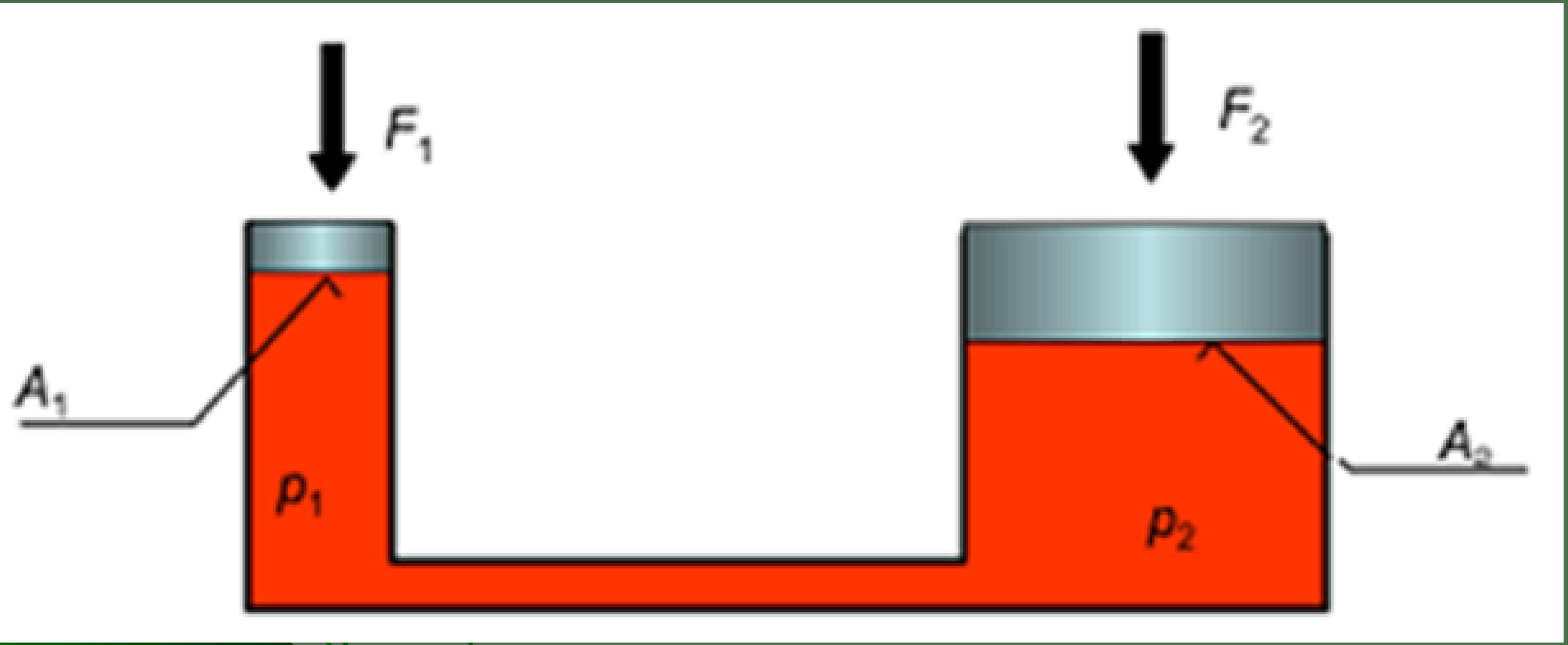
Application: Pressure Transmission



At equilibrium: $F_1 = F_2$ or $p_1 \cdot A_1 = p_2 \cdot A_2$ $\Rightarrow$ $\frac{p_1}{p_2} = \frac{A_2}{A_1}$

Problems

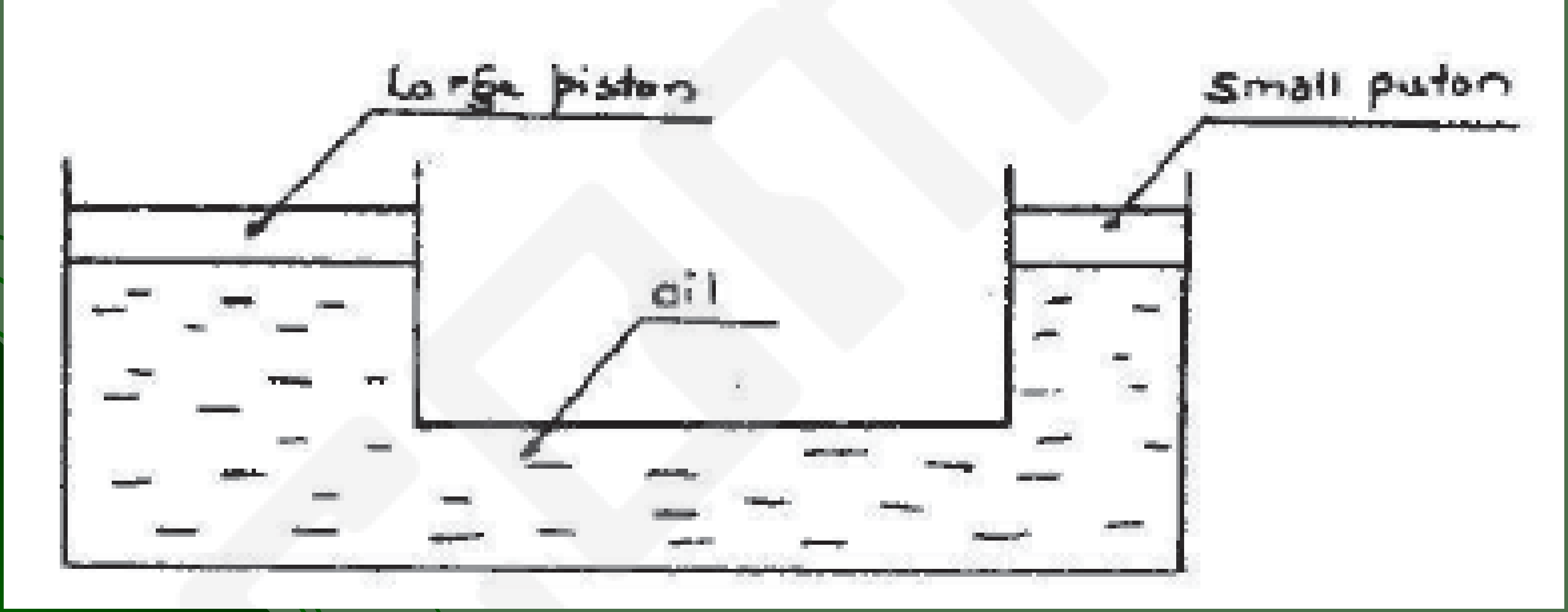
1. *In the hydraulic press shown below, a force of 100 N exerted on the small piston. Determine the upward force on the large piston. The area of the small piston is 50 x 10^2 mm^2 and the area of the large piston is 500 x 10^2 mm^2. Also find the distance moved by the large piston if the small piston moves by 100 mm.*

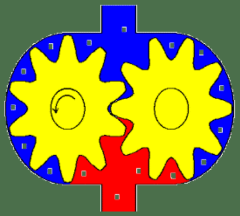


2. *Consider the arrangement shown in fig below. The piston diameter of small cylinder is 25 mm and the piston diameter of the large cylinder is 100 mm. The force required at the large cylinder piston is 2000 N. Calculate:*

i) The amount of force applied at the small cylinder piston.

ii) The distance the large piston will move if the small piston moves 100 mm.

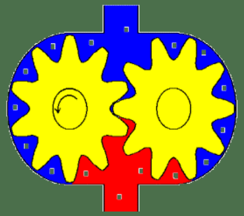




THE SOURCE OF HYDRAULIC POWER

PUMPS

PUMP



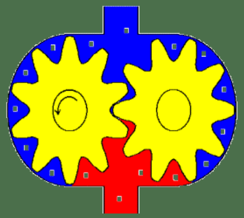
- INTRODUCTION

- A pump is device which converts mechanical energy into hydraulic energy.

TYPES OF PUMPS

- Dynamic (Non-positive Displacement)pumps
- Positive Displacement Pumps

Non-positive Displacement or Dynamic Pumps



- These are low pressure, high volume flow pumps.
- They are used only for fluid transport and are not used in fluid power industry because they cannot withstand high pressures.
- They have relatively small volumetric efficiency compared to positive pumps and low –pressure discharge output.
- Max pressure limited to 15 to 20 bars
- Examples of these pumps are:

  Centrifugal pumps (Impeller Type)

  Axial Pumps (Propeller Type)

Centrifugal and Axial pumps

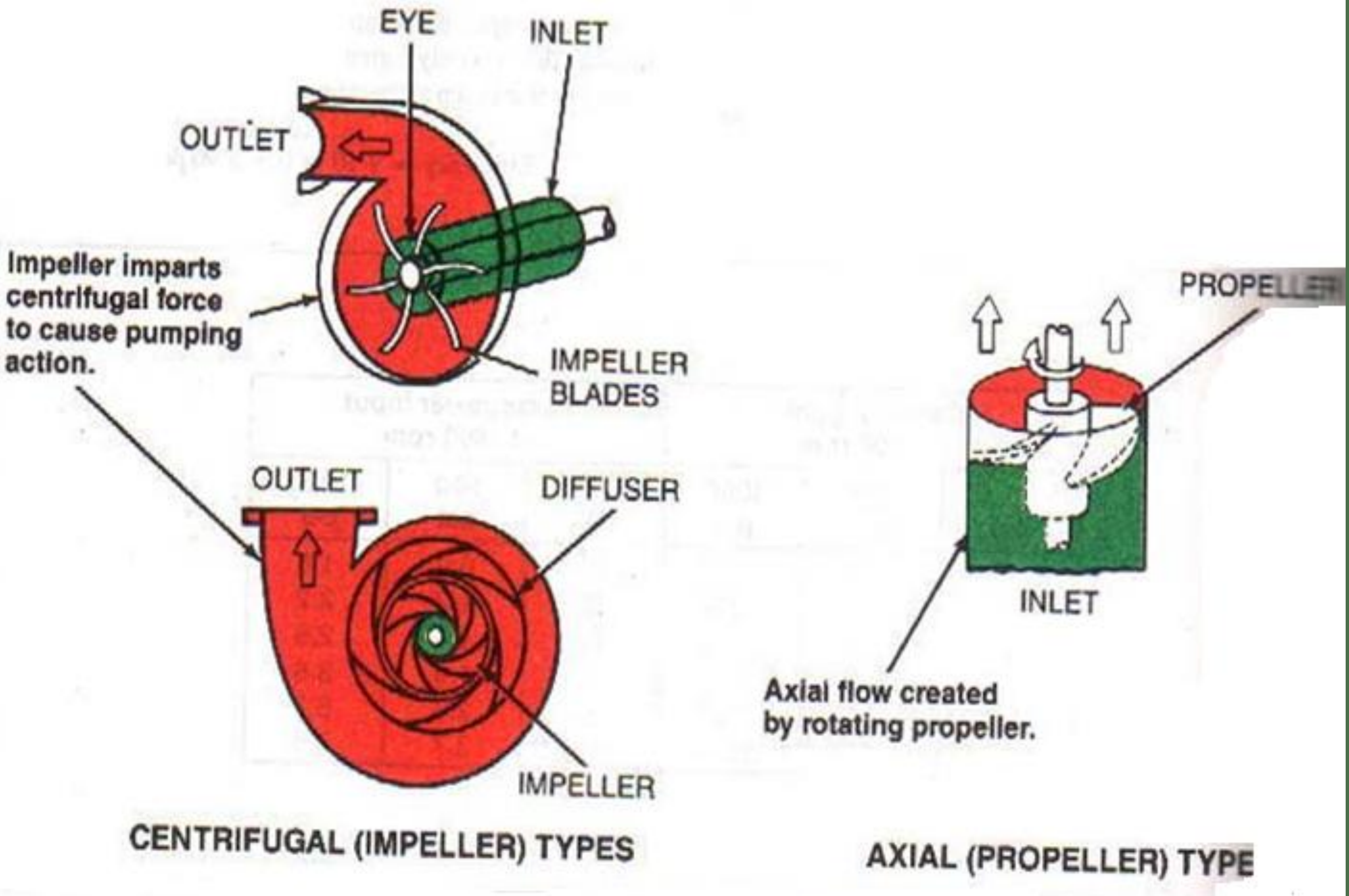
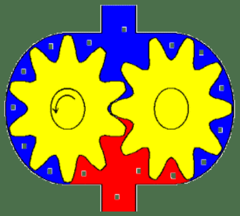


Fig. 1. Non -positive(Dynamic)displacement pumps

Positive Displacement Pumps



- This type is used universally for fluid power systems
- As the name implies, these pumps eject a fixed volume of flow into the hydraulic system per revolution of pump shaft
- They have large volumetric efficiency and high pressure discharge output.

These pumps have the following advantages:

- High pressure capacity, up to 700 bars
- Small, compact size
- Better performance characteristics, i.e., high efficiency over a wide range of speed and pressure.

Pumping Theory

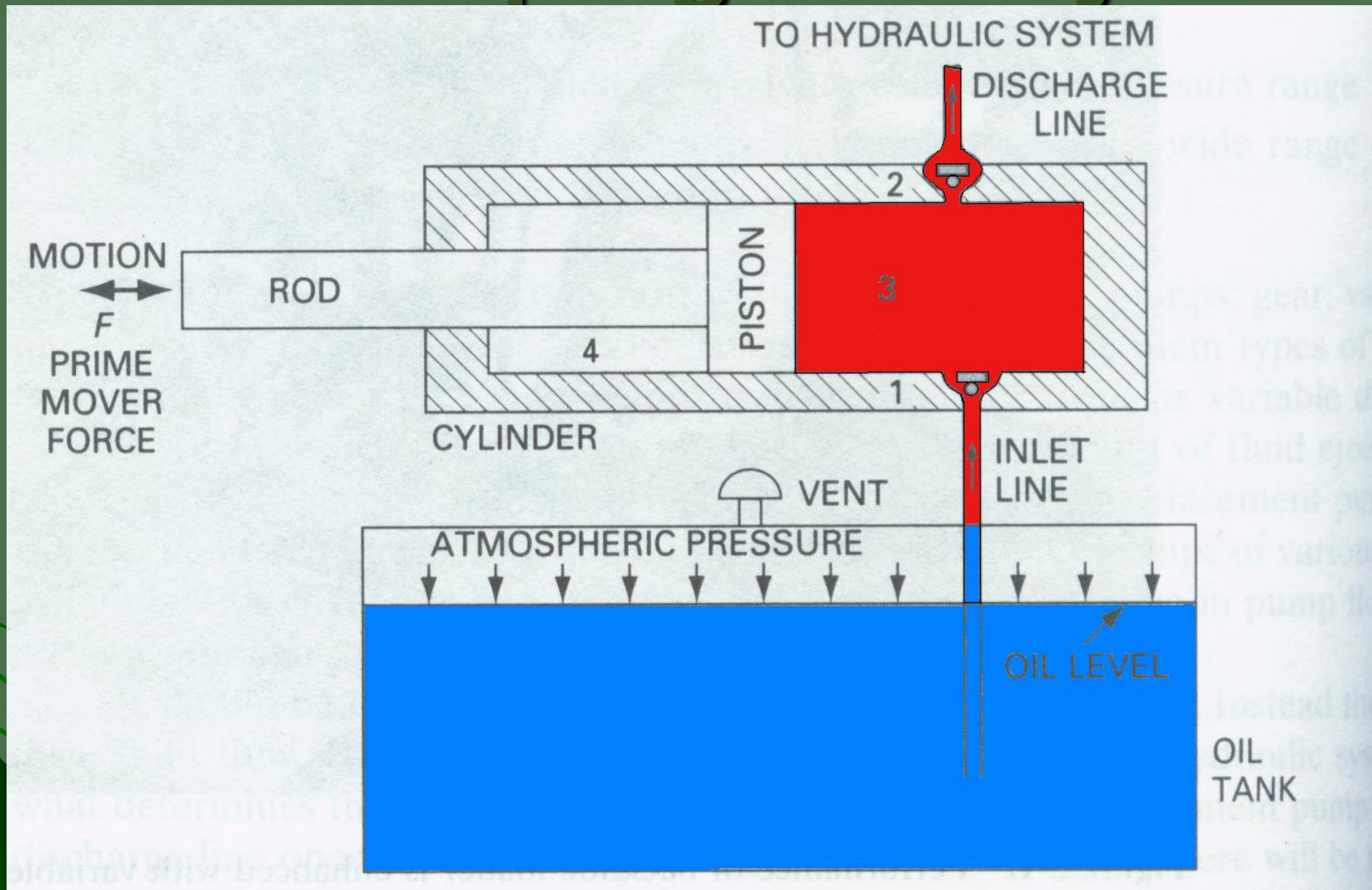
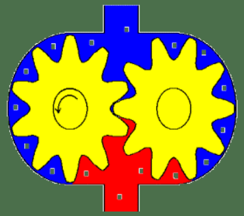


Fig. 2. Pumping action of a simple pis

Positive Displacement Pumps



1. **Gear pumps**

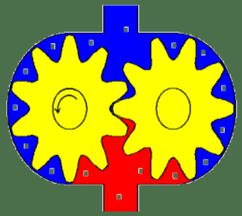
   a. External gear pumps

   b. Internal gear pumps

   c. Lobe pumps

   d. Screw pumps

Positive Displacement Pumps

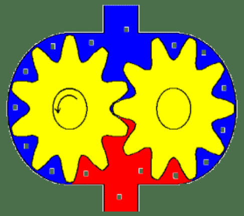


2. Vane pumps

a. Unbalanced vane pumps (fixed or variable displacement)

b. Balanced vane pumps (fixed displacement only)

Positive Displacement Pumps



3. Piston pumps

a. Axial design

b. Radial design

EXTERNAL GEAR PUMP

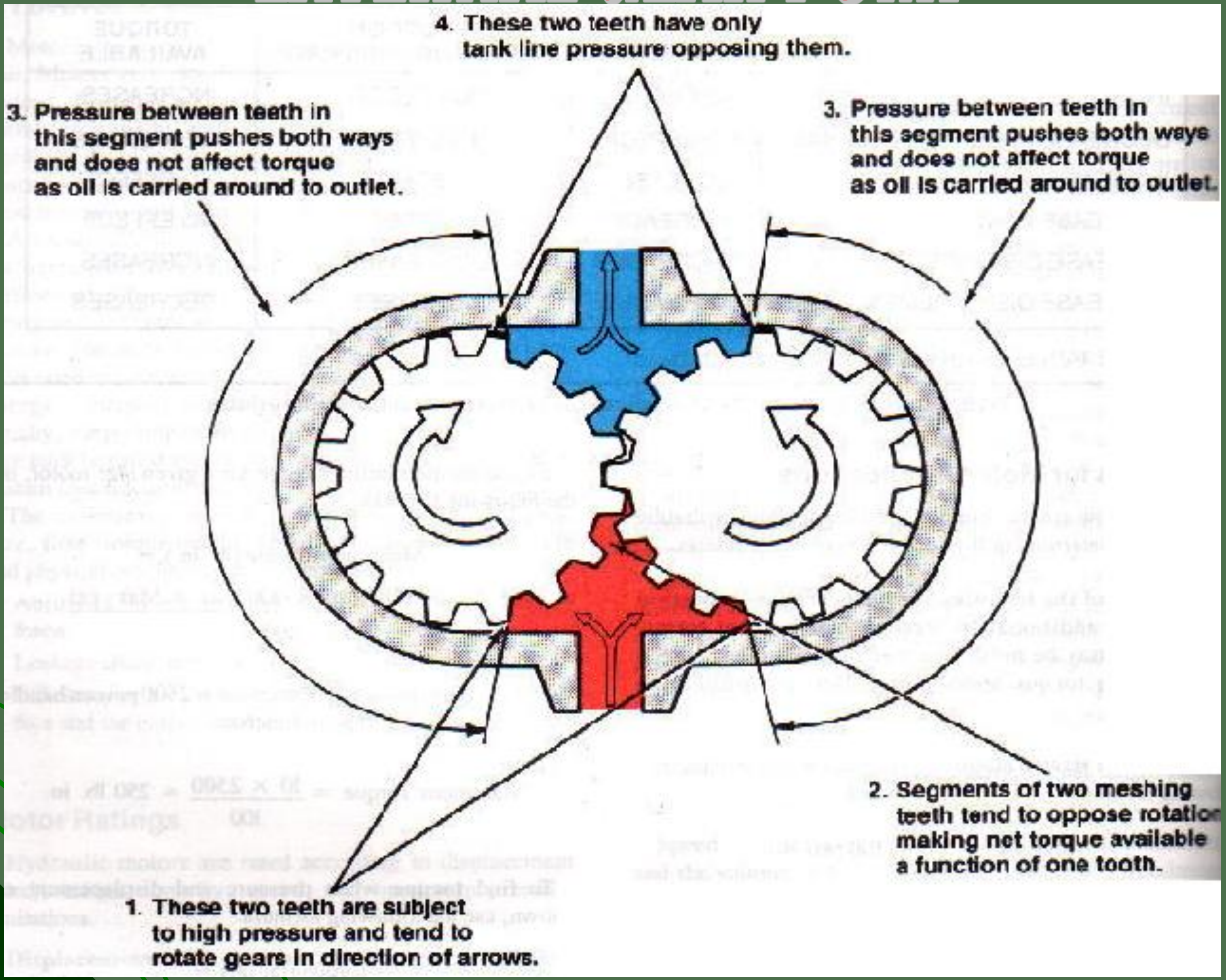
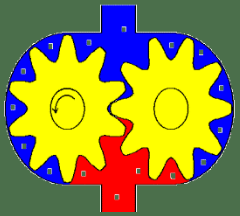
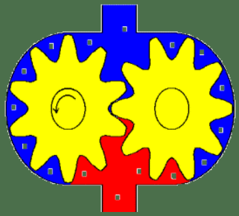


Fig. 3. External gear pump operation

Volumetric Displacement and Theoretical Flow Rate



- D_0= out side diameter of gear teeth in meter
- D_i= inside diameter of gear teeth in meter
- L= width of gear teeth in meter
- V_D=displacement volume of pump in cubic meter per revolution
- N= rpm of pump
- Q_T= theoretical pump flow – rate



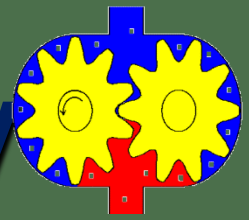
Volumetric displacement

- $V_D = \Pi/4(D_0^2 - D_i^2)L$

Theoretical flow rate

- $Q_T = V_D \times N$

Volumetric Efficiency



- There must be a small clearance (~25 microns) between the teeth tip and pump housing. As a result some of oil at the discharge port can leak directly back toward the suction port. This means actual flow rate Q_A is less than the theoretical flow rate Q_T

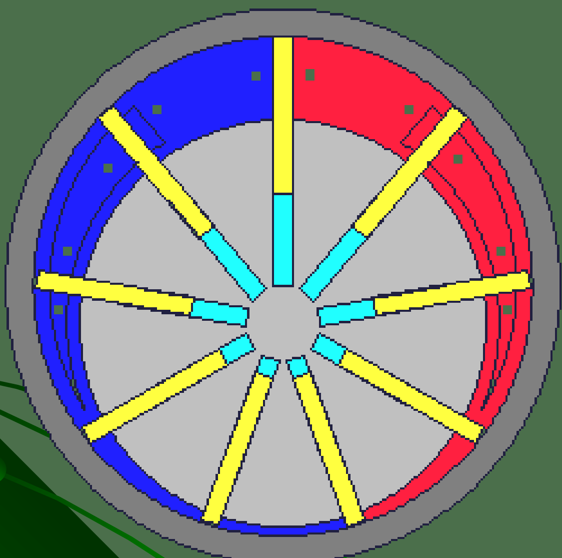
$$\eta_V = Q_A / Q_T$$

- Higher the discharge pressure , the lower the volumetric efficiency because internal leakage increases with pressure.

Numerical Problems

1. A gear pump has a 30mm outside diameter, a 20 mm inside diameter, and a 10 mm width. If the actual pump flow at 1800 rpm and rated pressure is 20 bar, what is the volumetric efficiency?
2. A gear pump has a 75mm outside diameter, a 50 mm inside diameter, and a 25 mm width. If the volumetric efficiency is 90% at rated pressure, what is the corresponding actual flow-rate? The pump speed is 1000 rpm.

VANE PUMP



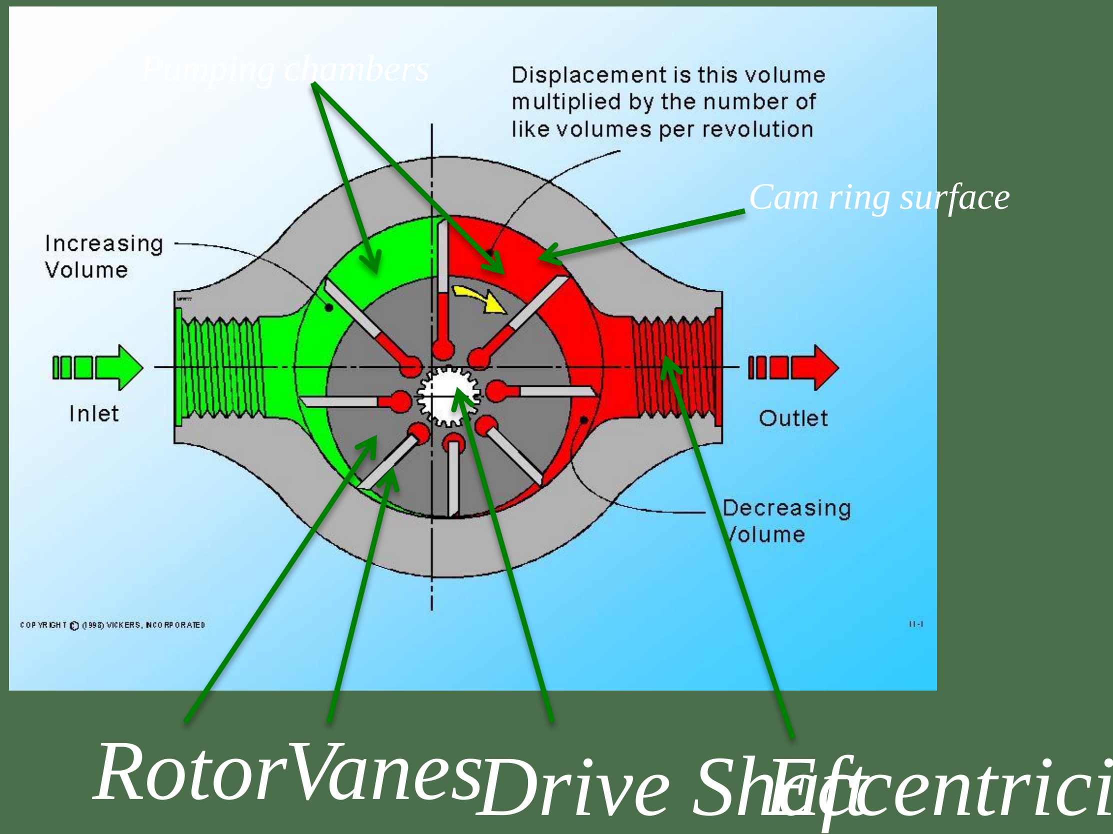
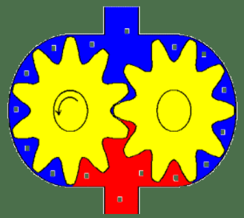


Fig. 4. Vane pump operation

Analysis of Volumetric Displacement



- D_c =diameter of cam ring (m)
- D_R =diameter of rotor (m)
- L = width of rotor (m)
- V_D = pump volumetric displacement (cubic meter)
- e = eccentricity (m)
- e_{max} = maximum possible eccentricity (m)
- V_{Dmax} =maximum possible volumetric displacement (m)

From geometry, we can find the maximum possible eccentricity:

$$e_{max} = \frac{D_C - D_R}{2}$$

This maximum value of eccentricity produces a maximum volumetric displacement

$$V_{Dmax} = \frac{\pi}{4}(D_C^2 - D_R^2)L$$

Noting that we have the difference between two squared terms yields

$$V_{Dmax} = \frac{\pi}{4}(D_C + D_R)(D_C - D_R)L$$

Substituting the expression for emax yields

$$V_{Dmax} = \frac{\pi}{4}(D_C + D_R)(2e_{max})L$$

The actual volumetric displacement occurs when emax=e

$$V_{Dmax} = \frac{\pi}{2}(D_C + D_R)eL$$

BALANCED VANE PUMP

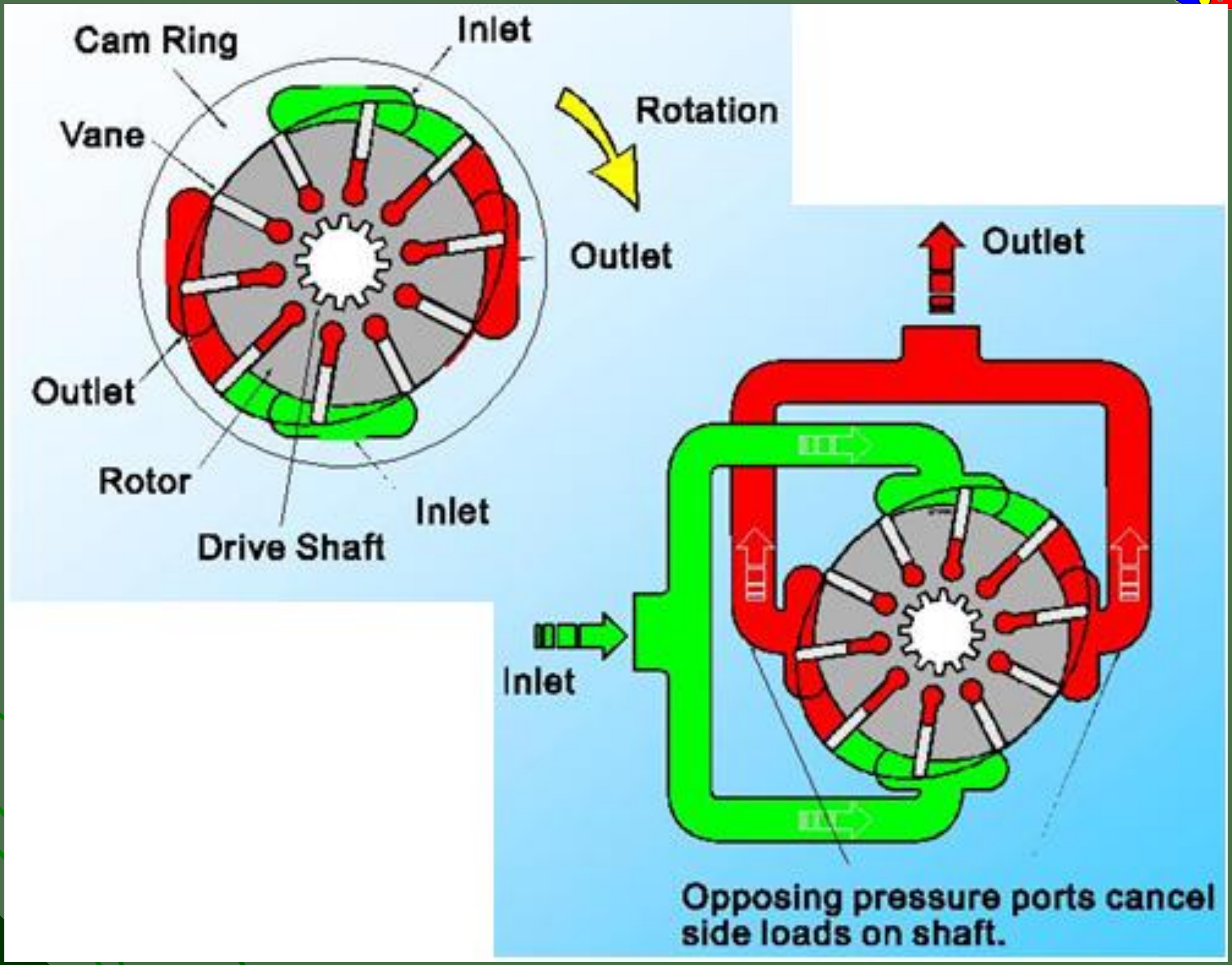
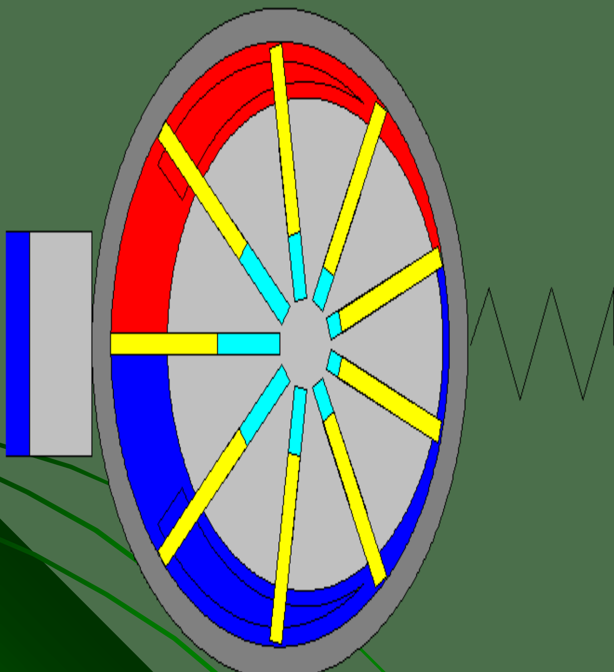


Fig. 5. Balanced Vane pump principal

Pressure compensated vane pump



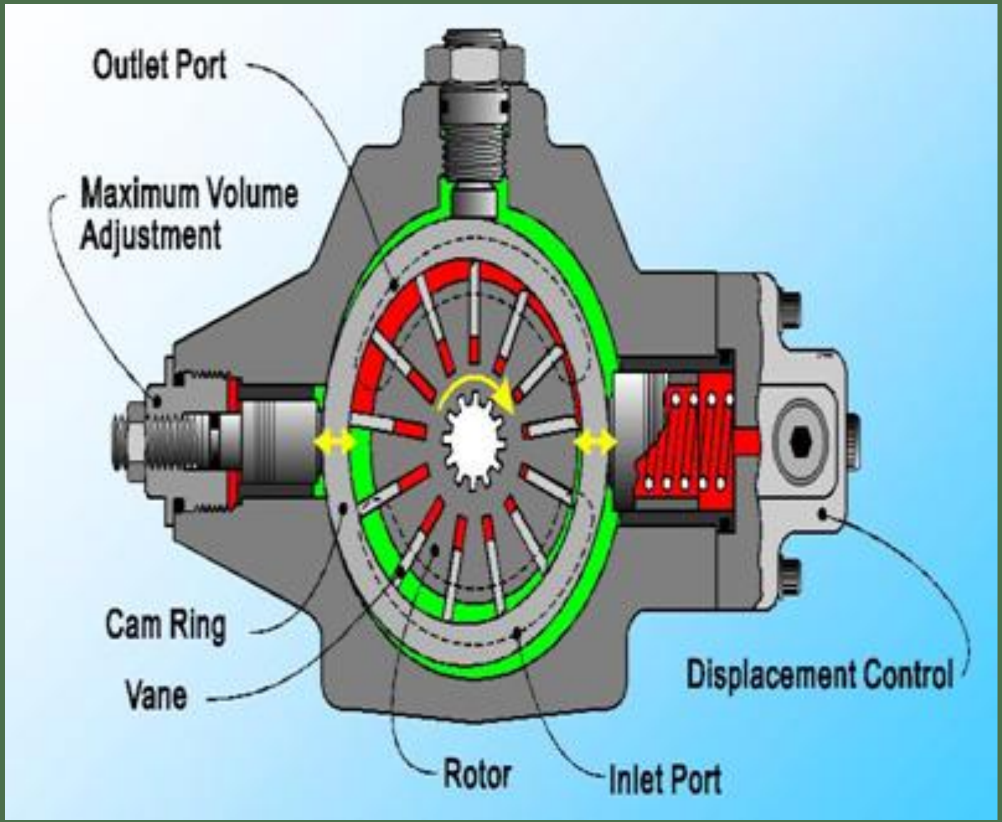
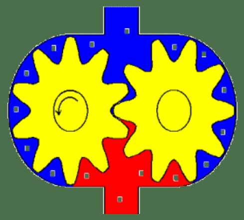


Fig. 7. Pressure compensated Vane pu

PISTON PUMPS



Piston pumps

Axial design   Radial design

Bent-axis design   Swash plate design

Axial piston pump (bent axis design)

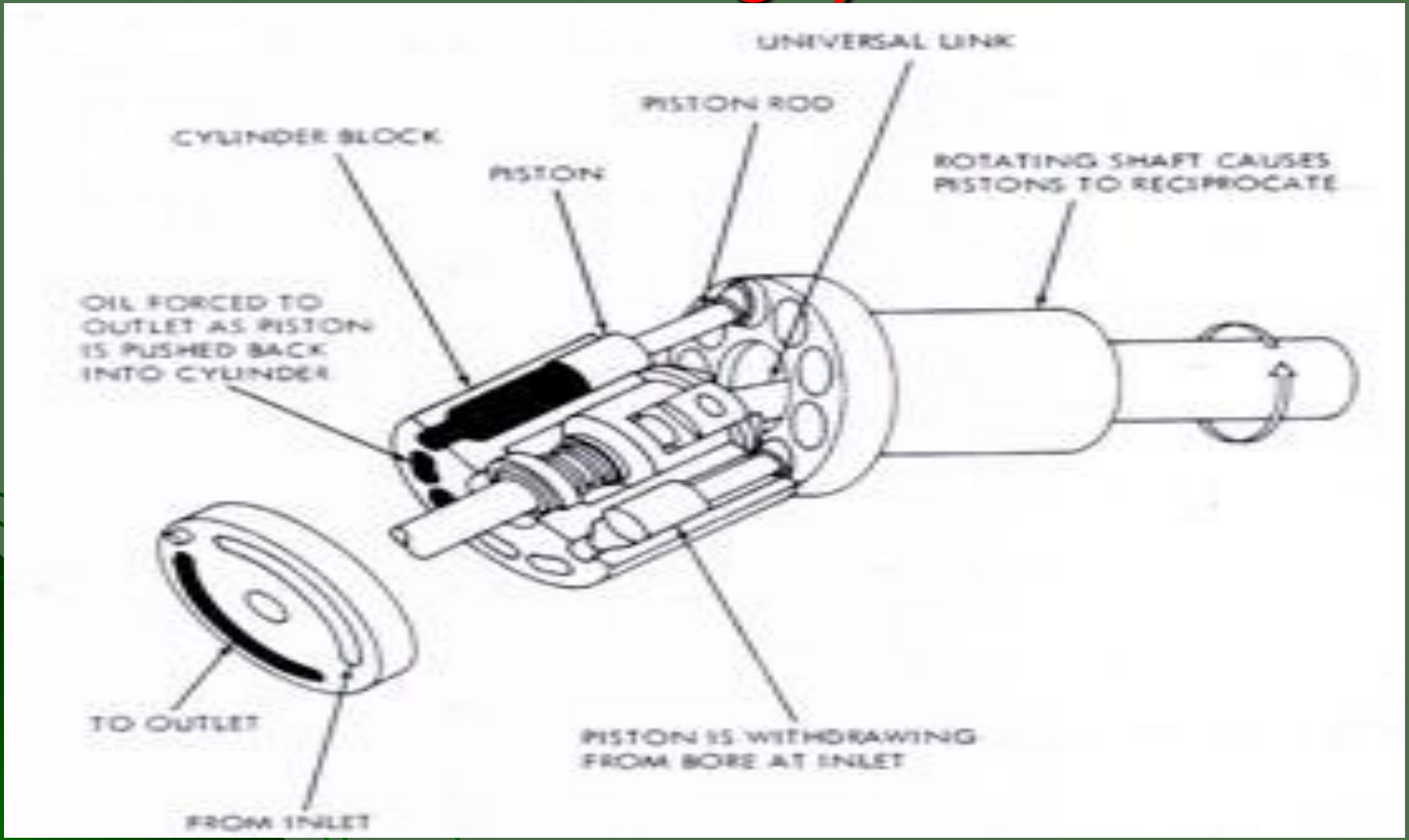
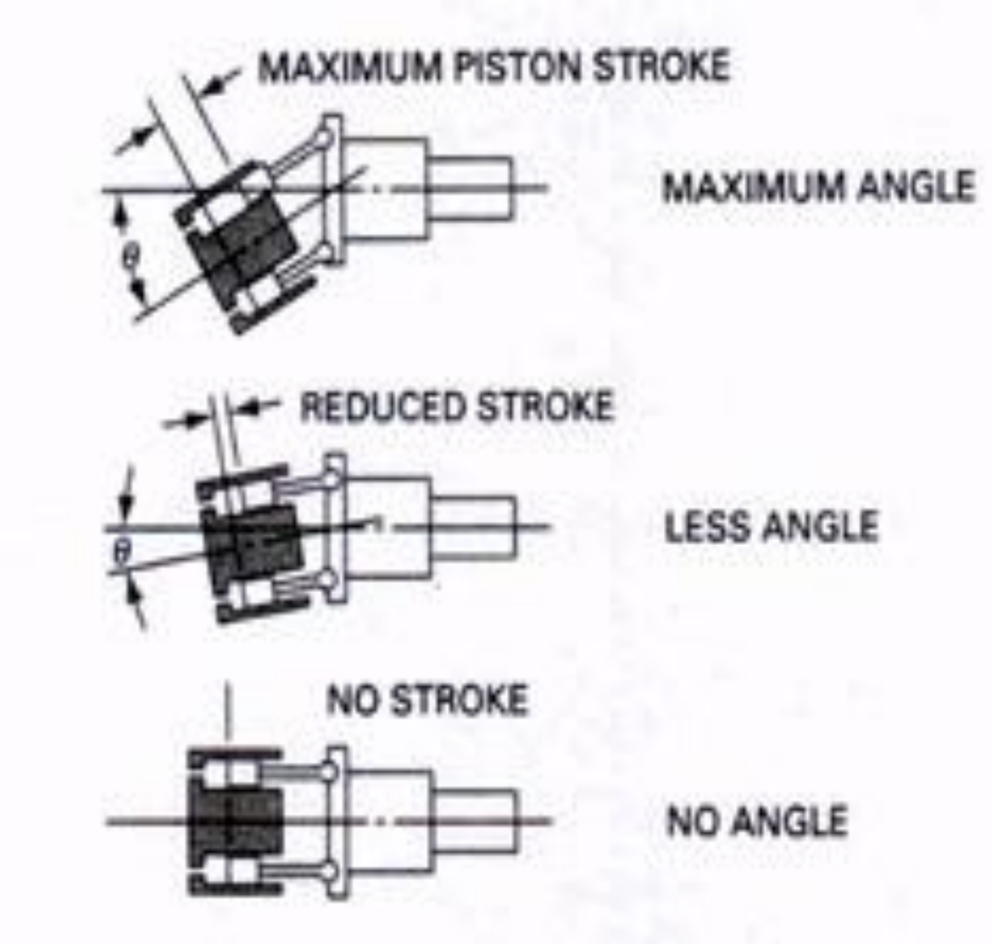


Fig. 8. Axial piston pump(bent axis typ



- The volumetric displacement of the pump varies with the offset angle θ as shown in figure.
- No flow is produced when the cylinder block centre line is parallel to the drive shaft centre line. This angle can vary from 0° to a maximum of 30°.

Fig. 9. Volumetric displacement changes with offset angle.

Analysis of volumetric displacement and theoretical flow rate

Let θ = offset angle, S = piston stroke, D = piston circle diameter,

Y = no. of pistons, A = area of piston, N = rpm of the drive shaft

Q_T = Theoretical flow-rate

From trigonometry we have,

$$\tan(\theta) = \frac{S}{D} \Leftrightarrow S = D\tan(\theta) \quad .... (1)$$

The total displacement volume equals the no. of pistons multiplied by the displacement volume per piston

Therefore, Volumetric displacement, $V_D = YAS$ ..... (2)

From (1) & (2), $V_D = YAD\tan(\theta)$ ...... (3)

Theoretical flow rate,

$$Q_T = DANY\tan(\theta) \quad ...... (4)$$

Problem:

What is the theoretical flow rate from a fixed-displacement axial piston pump with a nine- bore cylinder operating at 2000 RPM? Each bore has a diameter of 15 mm and stroke is 20 mm.

Solution: Theoretical flow rate is given by

$$Q_T = \text{Volume} \times \text{RPM} \times \text{Number of pistons}$$

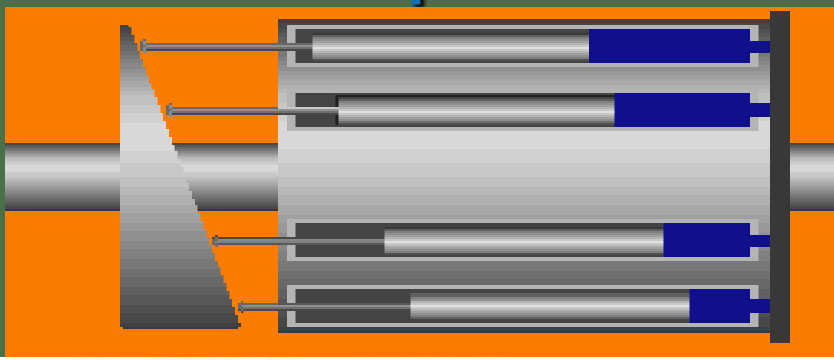
$$= \frac{\pi}{4} \times D^2 \times L \times N \times n$$

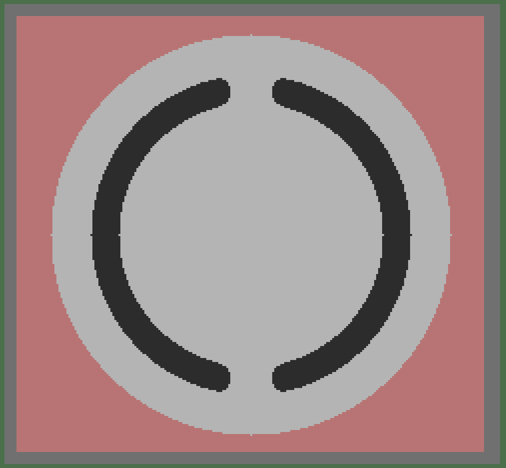
$$= \frac{\pi}{4} \times 0.015^2 \times 0.02 \times \frac{2000}{60} \times 9$$

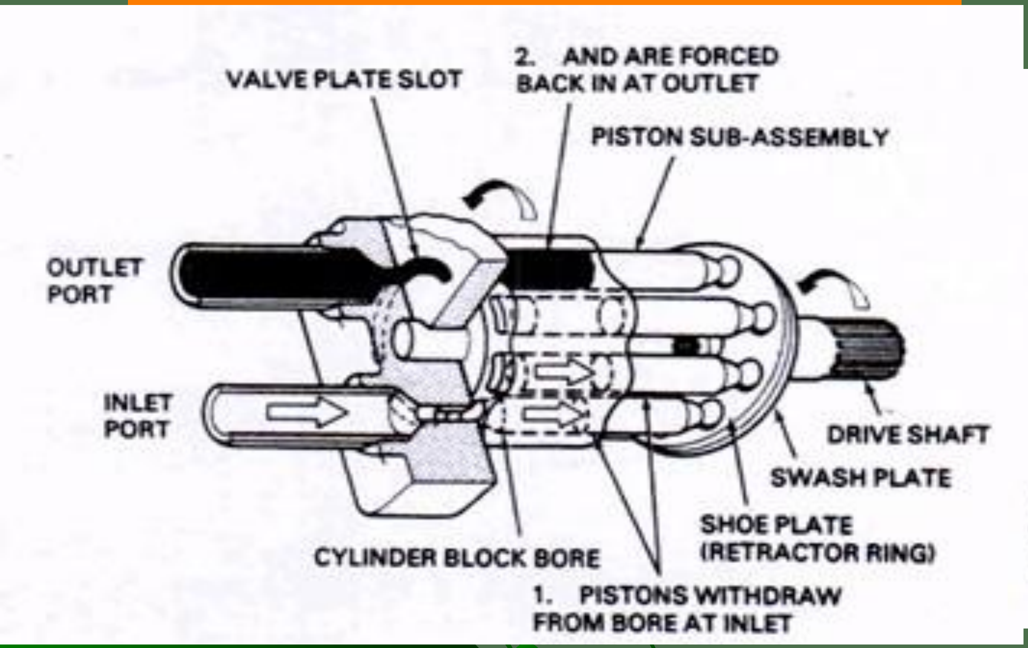
$$= 10.6 \times 10^{-3}\,\text{m}^3/\text{s}$$

$$= 1.06\ \text{LPS} = 63.6\ \text{LPM}$$

Axial piston pump (swash plate design)







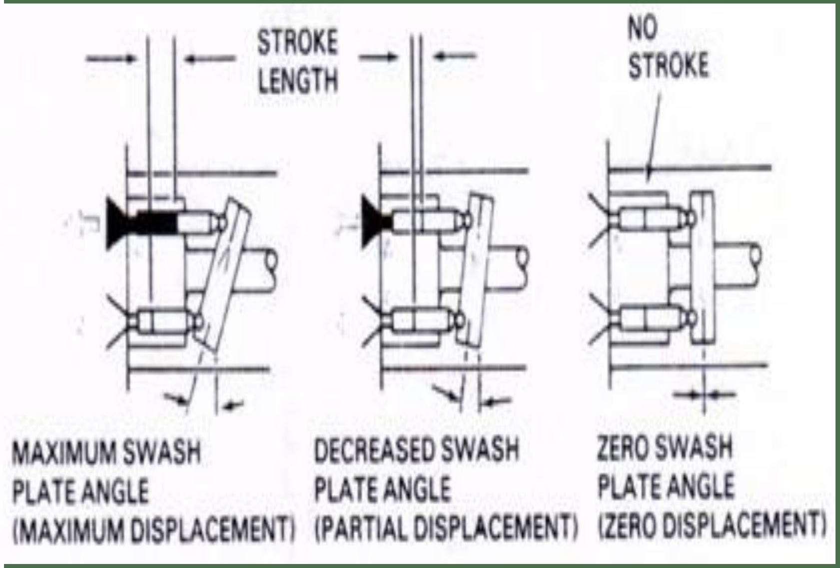
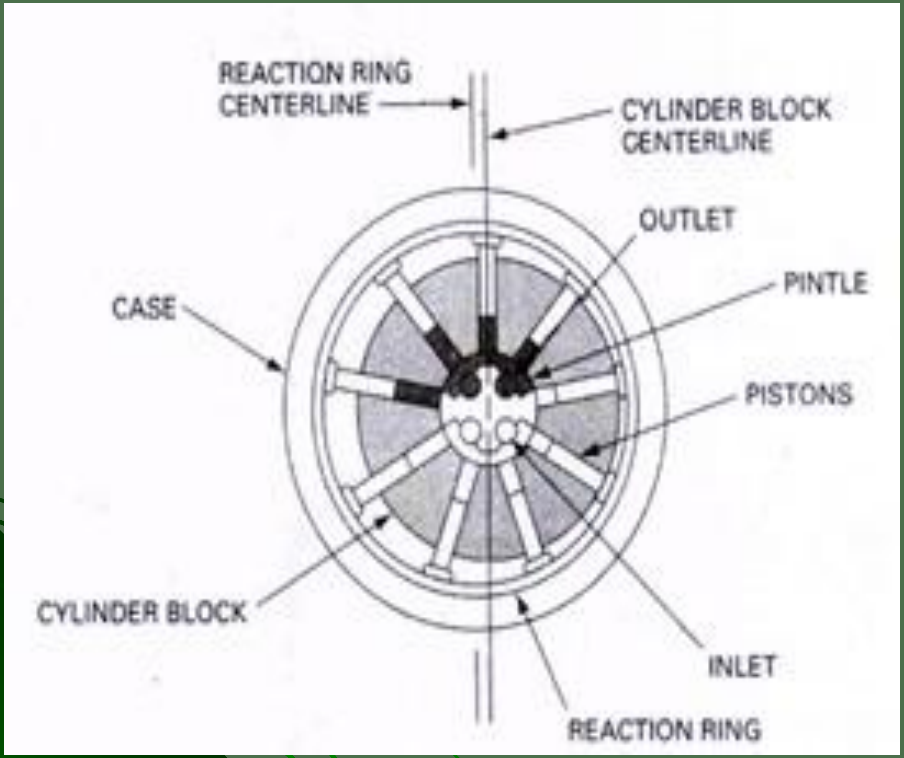


Fig. 10. variation in pump displacement

Radial piston pump



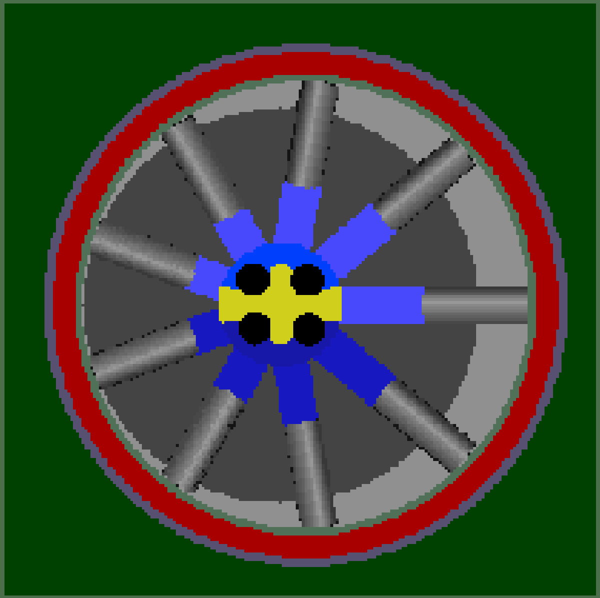
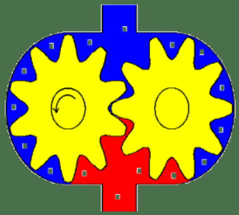


Fig. 11. Operation of radial piston pump.



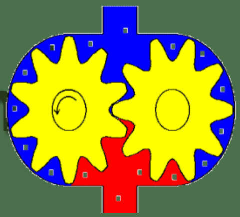
PUMP EFFICIENCIES

- Volumetric efficiency (η_V) :- *volumetric efficiency indicates the amount of leakage that takes place within the pump. This involves considerations such as manufacturing tolerances and flexing of the pump casing under design pressure operating condition.*

- *It is the ratio of actual flow rate produced by pump to the theoretical flow rate pump should produce.*

- $\eta_V = Q_A / Q_T$

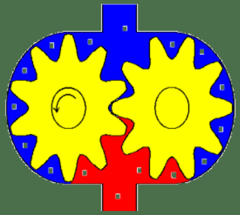
Mechanical efficiency(η_m



- ***Mechanical efficiency*** indicates the amount of energy losses that occur for reasons other than leakages. This includes

- *Friction in bearings and between other mating parts.*
- *It also includes energy losses due to fluid turbulence.*

Mechanical efficiency



- It is the ratio of pump output power assuming no leakage to the actual power delivered to pump.
- $(\eta_m) = pQ_T/T_A N$

- p= pump discharge pressure (^{3}Pa)
- Q_T= pump theoretical flow rate (m/s)
- T_A = actual torque delivered to pump (m)
- N = pump speed (rpm)

Mechanical efficiency in terms of torque

- ***It is the ratio of theoretical torque required to operate pump to the actual torque delivered to pump.***

$$(\eta_m) = \frac{T_T}{T_A}$$

THEORETICAL AND ACTUAL TORQUE

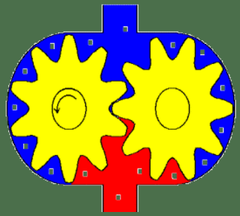
Theoretical torque(T_T)

$$\frac{V_D (m^3) \text{ X } p \text{ (pa)}}{2\Pi}$$

Actual torque (T_A)

$$T_A = \frac{\text{actual power delivered to pump (W)}}{N(\text{rad/s})}$$

Overall efficiency



The overall efficiency considers all losses hence it is defined as follows.

$$\text{Overall efficiency} = \frac{\text{actual power delivered by pump}}{\text{actual power delivered to pump}}$$

- **The overall efficiency can also be represented mathematically as follows**
- $\eta_o = \eta_v \times \eta_m$

$$\eta_o = \eta_v \times \eta_m = \frac{Q_A}{Q_T} \times \frac{pQ_T}{T_A N}$$

$$\eta_o = \frac{pQ_A}{T_A N}$$

The actual power delivered to a pump from a prime mover via a rotating shaft is called brake power and the actual power delivered by a pump to the fluid is called hydraulic power.

CHAPTER - 2

HYDRAULIC ACTUATORS AND MOTORS

ACTUATORS

- Hydraulic cylinders (linear actuators):- extend and retract a piston rod to provide a pull push force to drive the external load along a straight line path.
- Hydraulic motors (rotary actuators):- rotate a shaft to provide a torque to drive the load along a rotary path.

DIFFERENCE BETWEEN HYDRAULIC MOTOR AND PUMP

- **PUMP :-** Hydraulic pump is a device which converts mechanical energy supplied by the electric motor in to hydraulic energy.

- **MOTOR:-** Hydraulic motor is a device which converts hydraulic energy supplied by the hydraulic pump into mechanical energy to do some useful work.

DIFFERENCE BETWEEN HYDRAULIC MOTOR AND PUMP

- **PUMP :-** pump perform the function of adding energy to a hydraulic system for transmission to some remote point.

- **MOTOR:-** They extract energy from a fluid and convert it to a mechanical output to perform useful work.

DIFFERENCE BETWEEN HYDRAULIC MOTOR AND PUMP

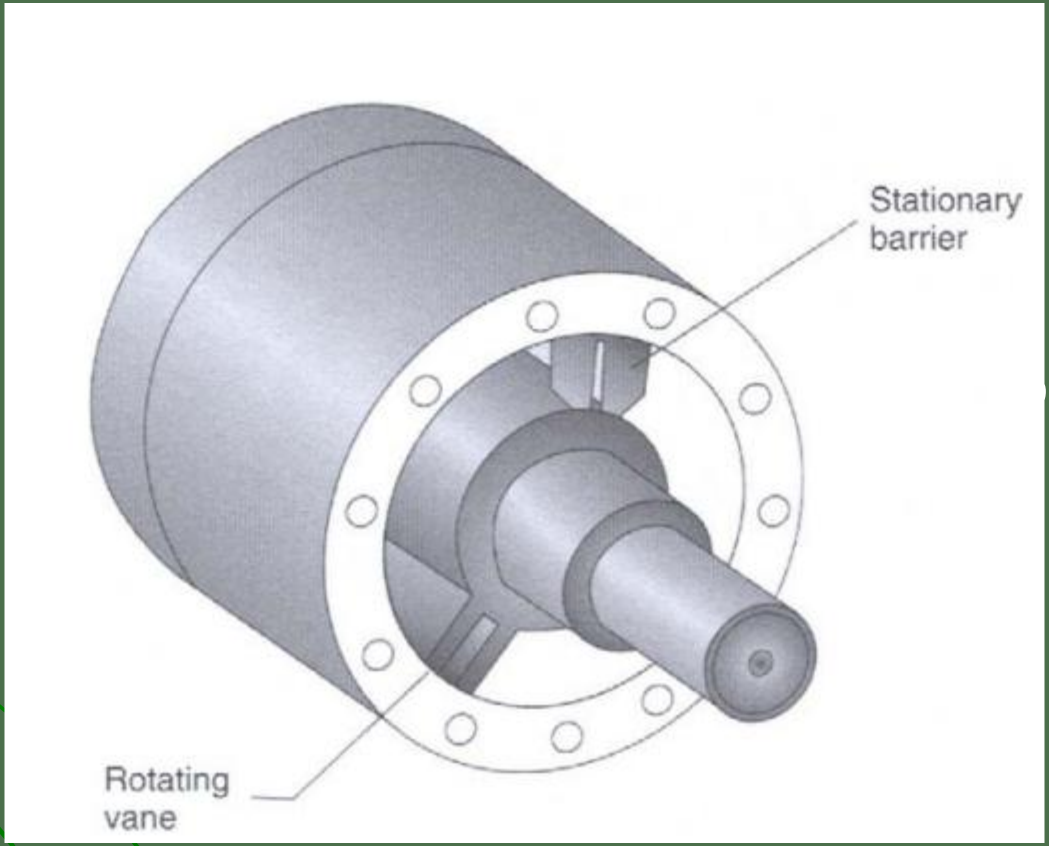
- **PUMP:-** Fluid pushed by the pump to hydraulic system.

- **MOTOR:-** Fluid pushes on the internal surface area of the motor, developing torque.

CLASSIFICATION OF HYDRAULIC MOTORS

- **Limited rotation hydraulic motors**
- **Continuous rotation hydraulic motors**

LIMITED ROTATION HYDRAULIC MOTOR



n angle = 28

LIMITED ROTATION HYDRAULIC ACTUATOR

TORQUE CAPACITY ANALYSIS OF LIMITED ROTATION HYDARULIC ACTUATOR WITH SINGLE ROTATING VANE

Let

R_R be the outer radius of the rotor in meters

R_V be the outer radius of the vane in meters

L be the width of the vane in meters

P be the hydraulic pressure in psi or Pascal

F be the hydraulic force acting on the vane in Newton

A be the surface area of the vane in contact with oil in meter^2 and

T be the torque capacity in Newton meter.

TORQUE CAPACITY ANALYSIS OF LIMITED ROTATION HYDARULIC ACTUATOR WITH SINGLE ROTATING VANE

- Force on the vane $F = P \times A$

$$= P(R_V - R_R)L$$

Torque $$T = P(R_V - R_R)L\left\{\frac{(R_V + R_R)}{2}\right\}$$

On rearranging, the equation can be written as:

$$T = \left\{\frac{PL}{2}\right\}(R_V{}^2 - R_R{}^2)$$

TORQUE CAPACITY ANALYSIS OF LIMITED ROTATION HYDARULIC ACTUATOR WITH SINGLE ROTATING VANE

Volumetric displacement (V_d) is given by

$$V_D = \pi \, (R_V^2 - R_R^2) \, L$$

Combining the above two equations, we get

$$T = \frac{(P V_D)}{6.28}$$

It is observed from the above equation that torque capacity can be increased either by increasing the pressure or by increasing the volumetric displacement or both.

CONTINUOUS ROTATION HYDRAULIC MOTORS

- Continuous rotation motors are actuators which can rotate continuously.

- Classification:
- Gear motors
- Vane motors
- Piston motors

GEAR MOTOR

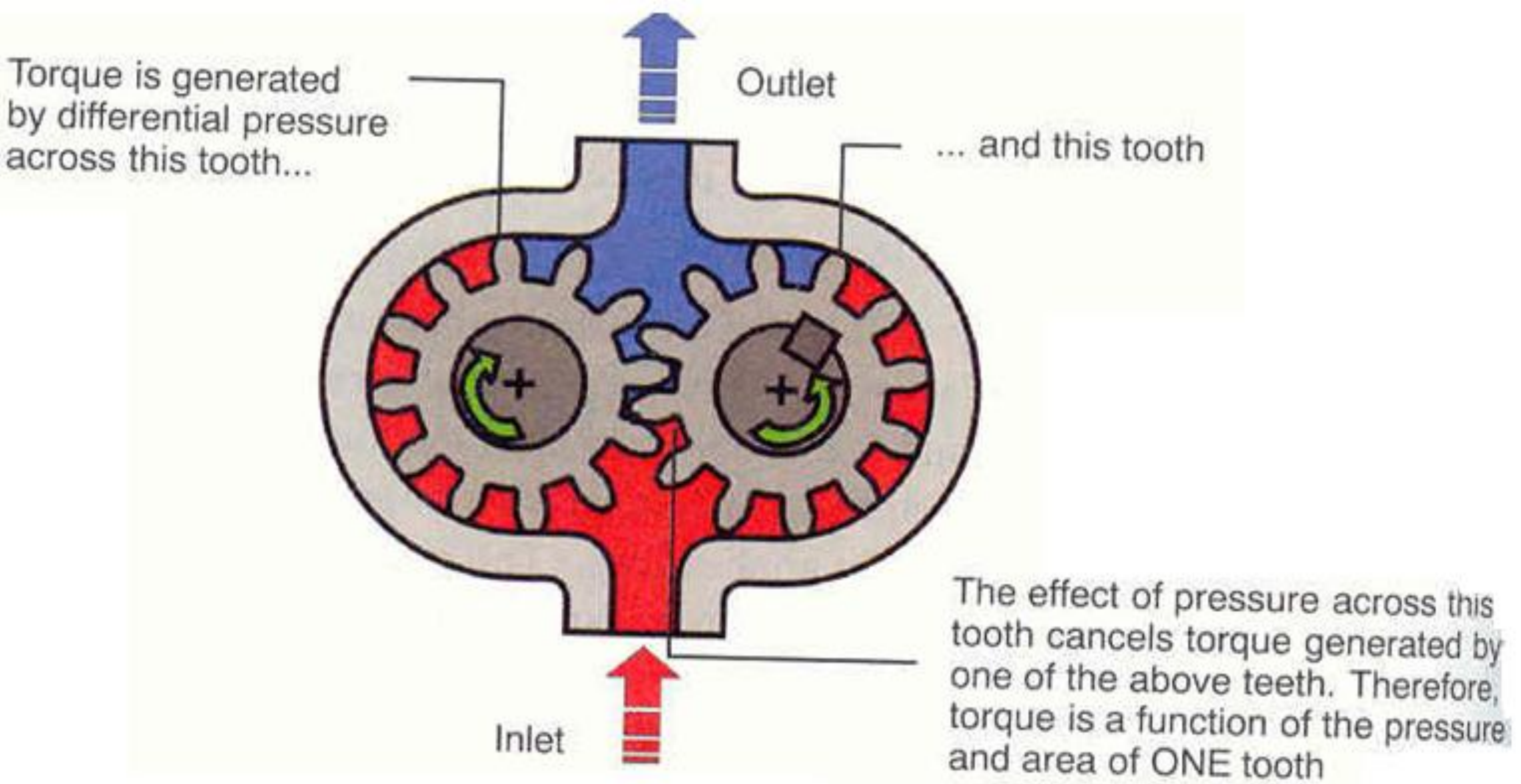
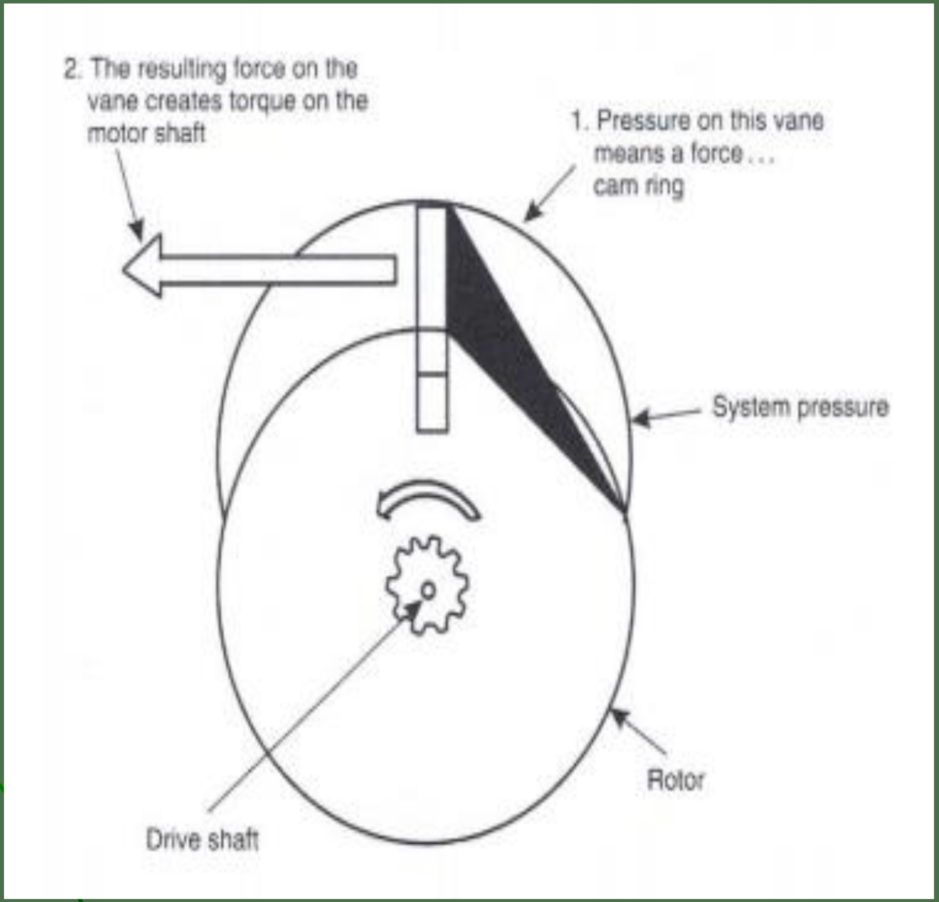


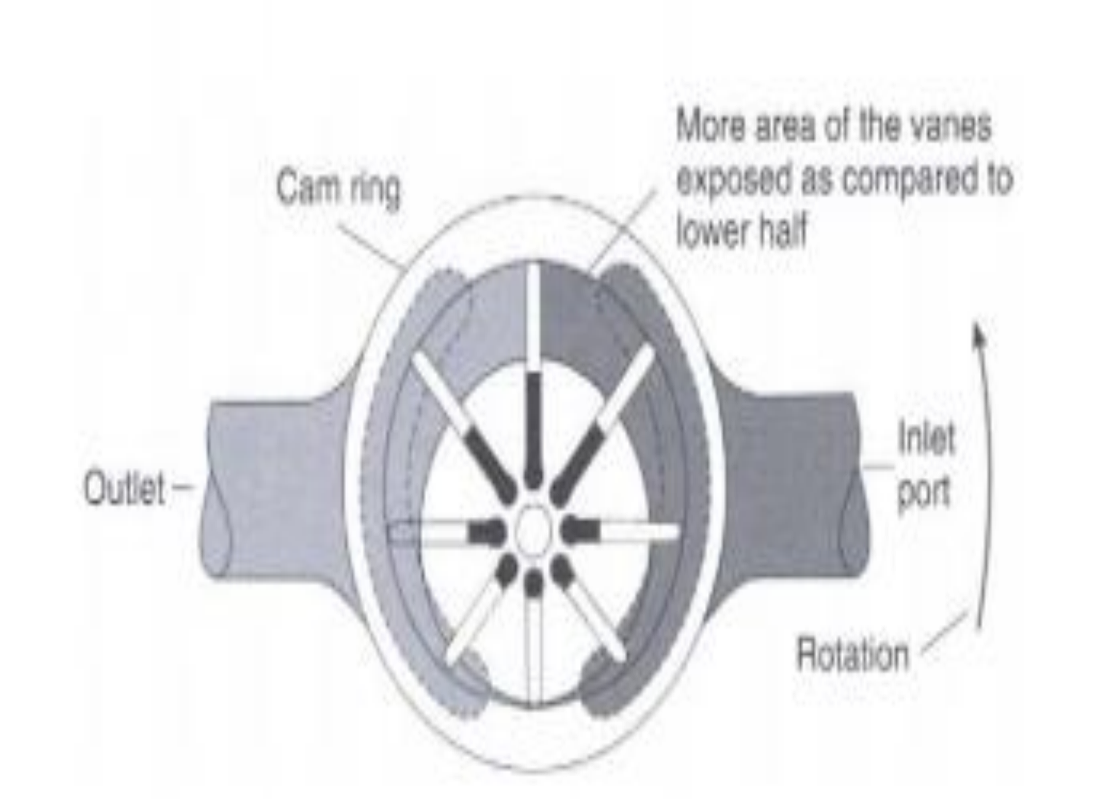
Fig. Torque generation in an external gear motor

VANE MOTOR

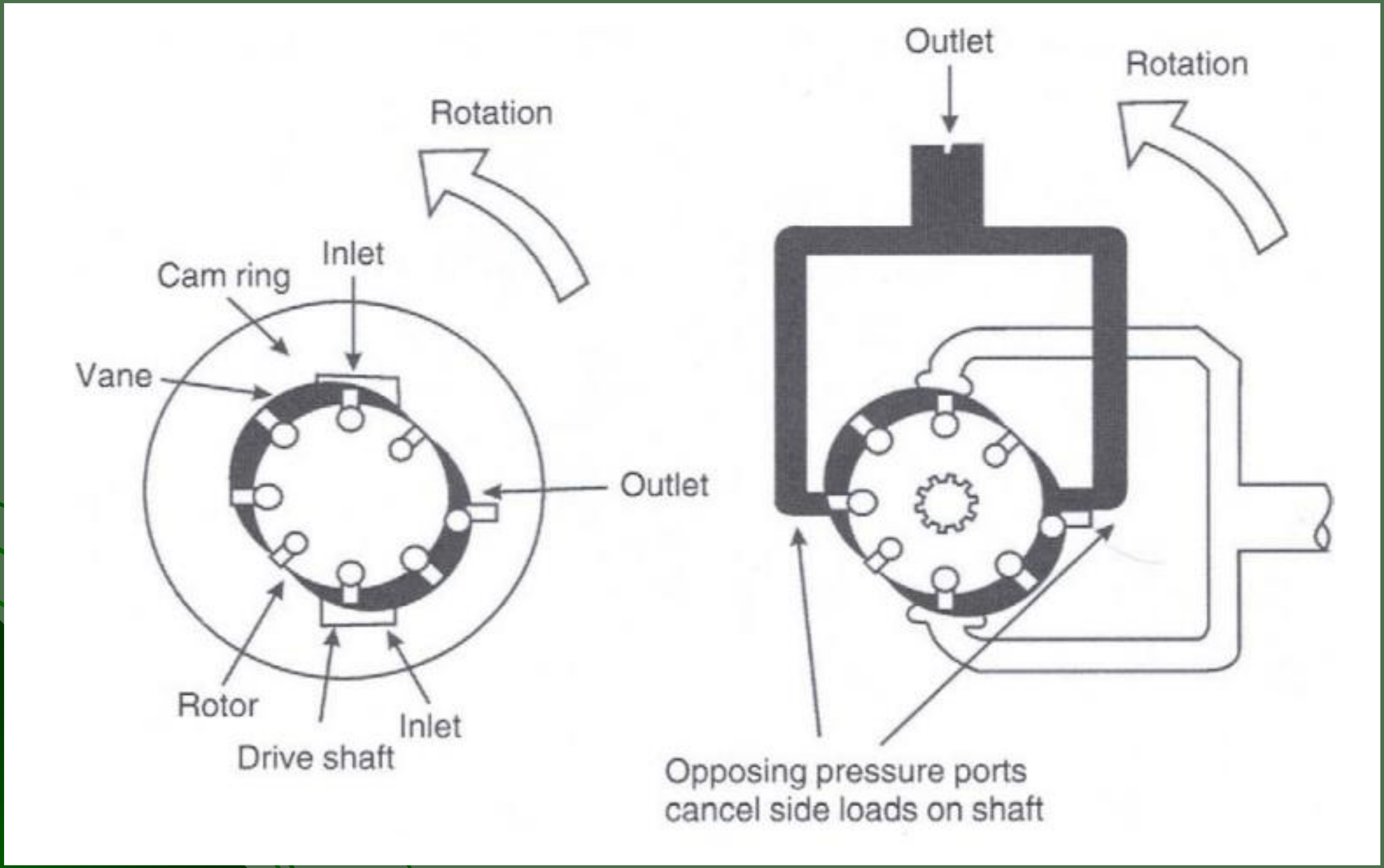


2. The resulting force on the vane creates torque on the motor shaft
1. Pressure on this vane means a force . . .
cam ring
System pressure
Rotor
Drive shaft

UNBALANCED VANE MOTOR



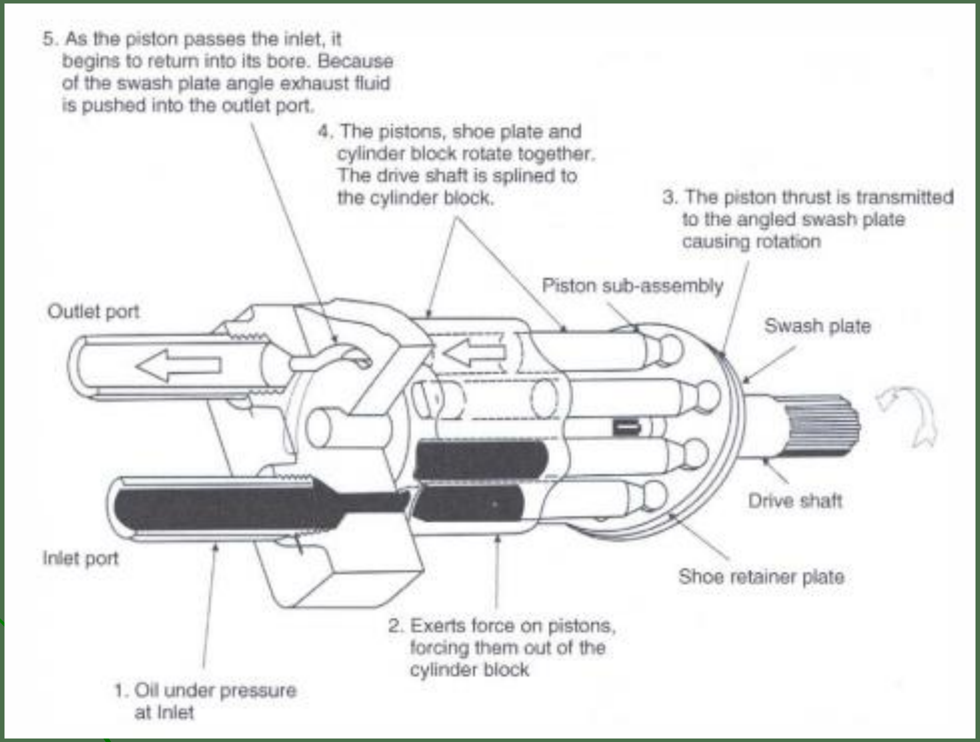
BALANCED VANE MOTOR



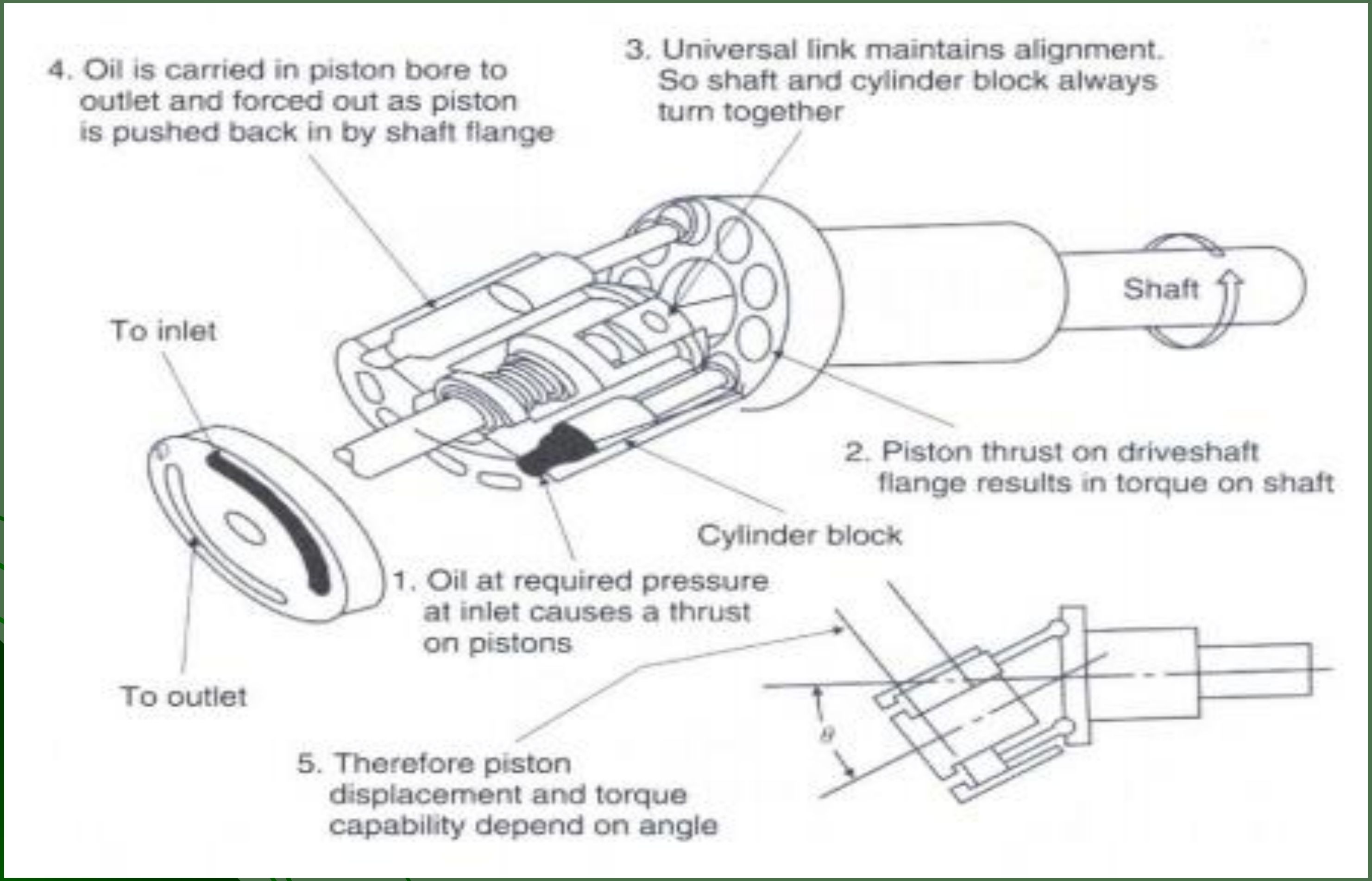
PISTON MOTORS

- IN – LINE PISTON MOTOR (SWASH PLATE DESIGN)
- BENT AXIS PISTON MOTOR

IN – LINE PISTON MOTOR (SWASH PLATE)



BENT AXIS TYPE PISTON MOTOR



HYDRAULIC MOTOR PERFORMANCE

- The performance of hydraulic motors depends on lot of factor such as:

- Manufacturing precision
- Maintenance of close tolerance
- Internal leakage
- Friction between internal parts
- Internal fluid turbulence

TYPICAL GEAR, VANE AND PISTON MOTOR OVERALL EFFICIENCIES

Type of Motor	Efficiency (%)
Gear motors	70–75
Vane motors	75–85
Piston motors	85–95

VOLUMETRIC EFFICIENCY

The volumetric efficiency (η_v) of a hydraulic motor is given by

$$\eta_v = \left(\frac{Q_T}{Q_A}\right) \times 100$$

Where

Q_T is equal to the theoretical flow rate the motor should consume and

Q_A is the actual flow rate consumed by the motor.

THEORITICAL TORQUE

$$T_T = \frac{V_D \times P}{6.28}$$

Where

P is the pressure in Pascal and

V_D is the volumetric displacement measured in m^3/rev.

MECHANICAL EFFICIENCY

The mechanical efficiency (η_m) of a hydraulic motor is given by

$$\frac{\text{Actual torque delivered by the motor}}{\text{Torque which the motor should theoretically deliver)}} \times 100$$

$$\eta_m = \left(\frac{T_A}{T_T}\right) \times 100$$

Where

T_A is the actual torque delivered by the motor and

T_T is the theoretical motor torque.

ACTUAL TORQUE

$$T_A = \frac{\text{Actual motor wattage}}{N} \quad \text{in metric units}$$

OVERALL EFFICIENCY

$$\text{Overall efficiency} = \frac{\text{Actual power delivered by the motor}}{\text{Actual power delivered to the motor}}$$

$$\eta_o = \frac{(\eta_v \times \eta_m)}{100}$$

$$\eta_o = \frac{T_A \times N}{P \times Q_A}$$

Where

T_A is in Newton meter

N is in rad/s

P is in Pascal and

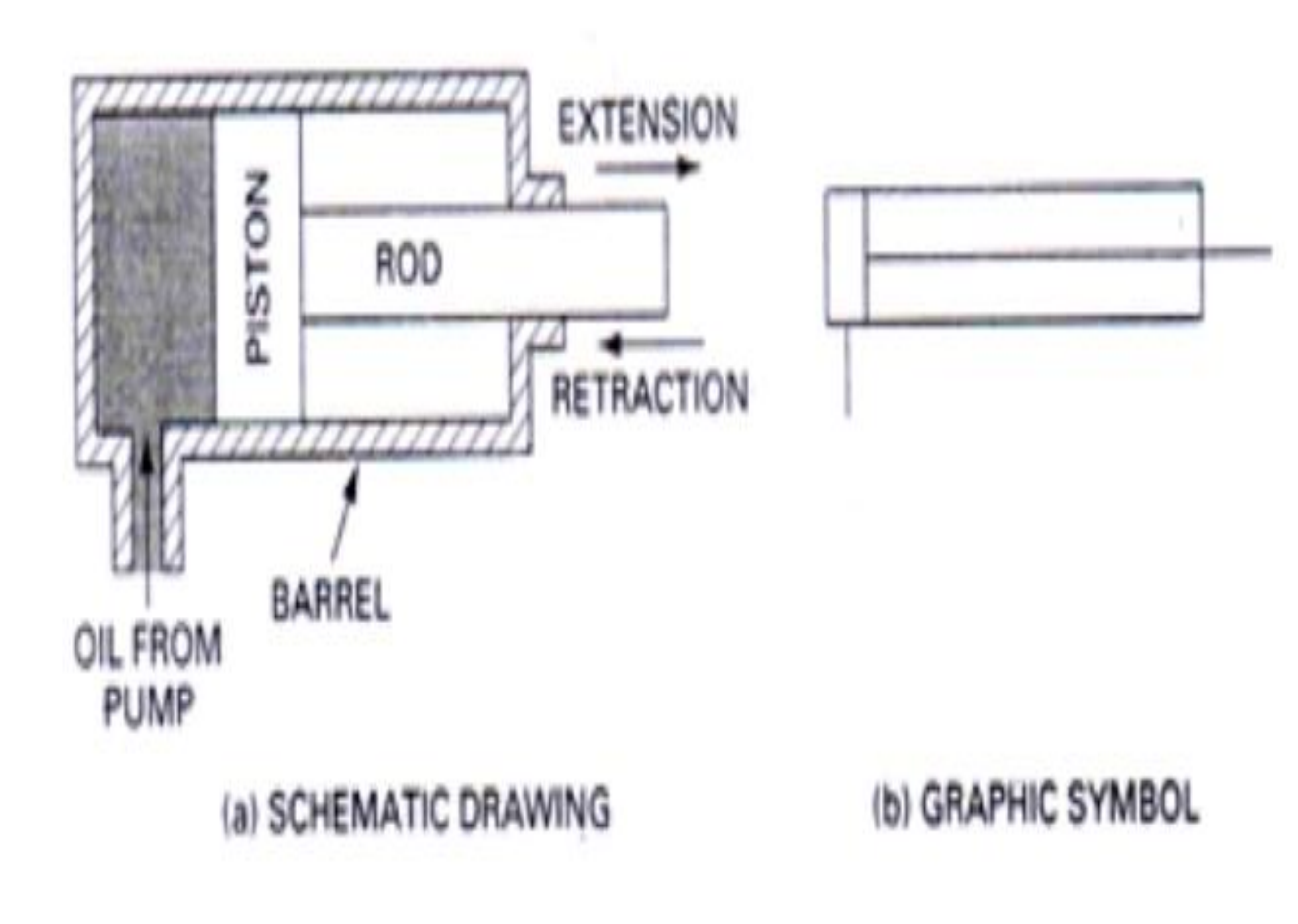
Q_A is in m^3/s.

HYDRAULIC CYLINDERS AND CUSHINING DEVICES

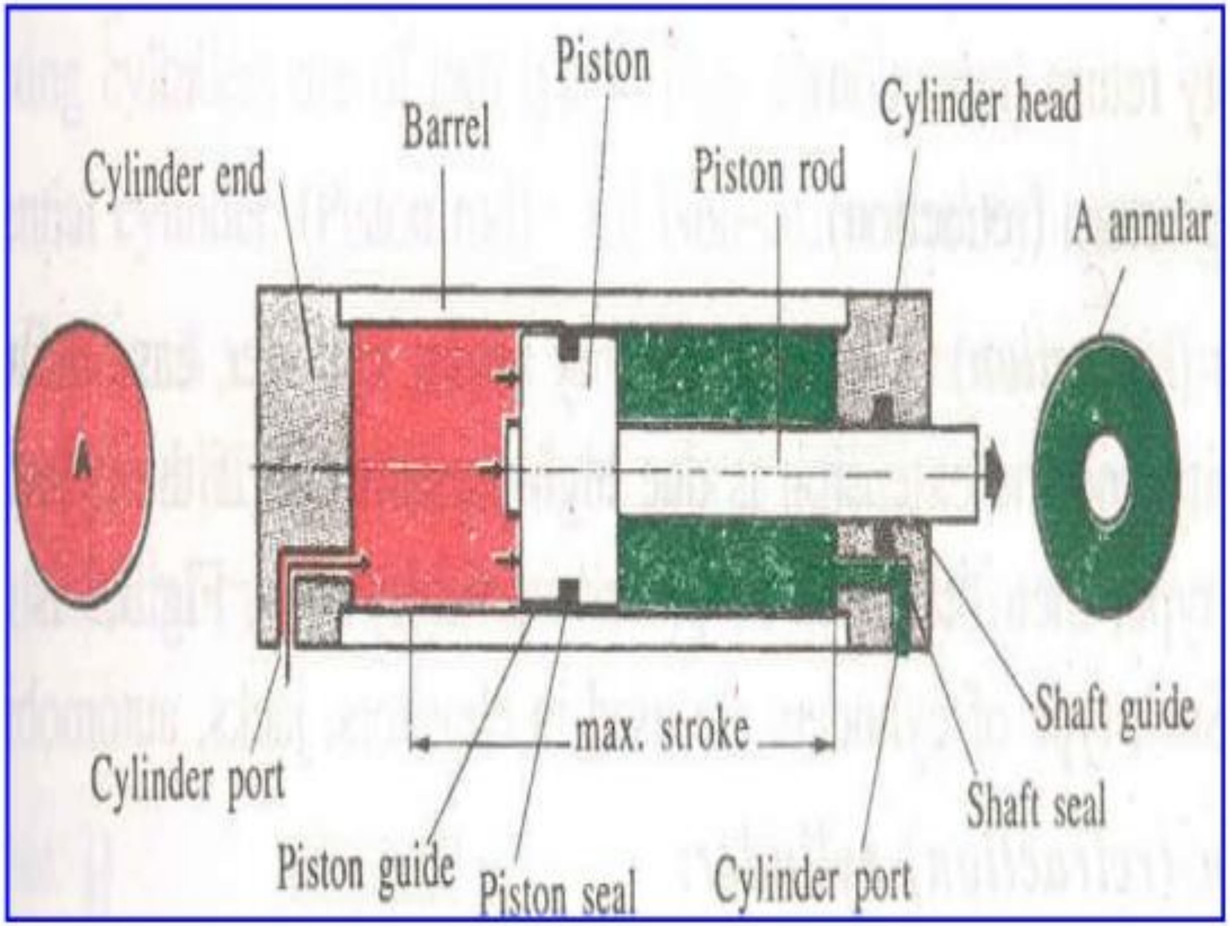
- LINEAR HYDRAULIC ACTUATORS (CYLINDERS).

- <u>Common types</u>
- Single acting cylinders
- Double acting cylinders
- Tandem cylinders
- Telescopic cylinders

SINGLE ACTING CYLINDER

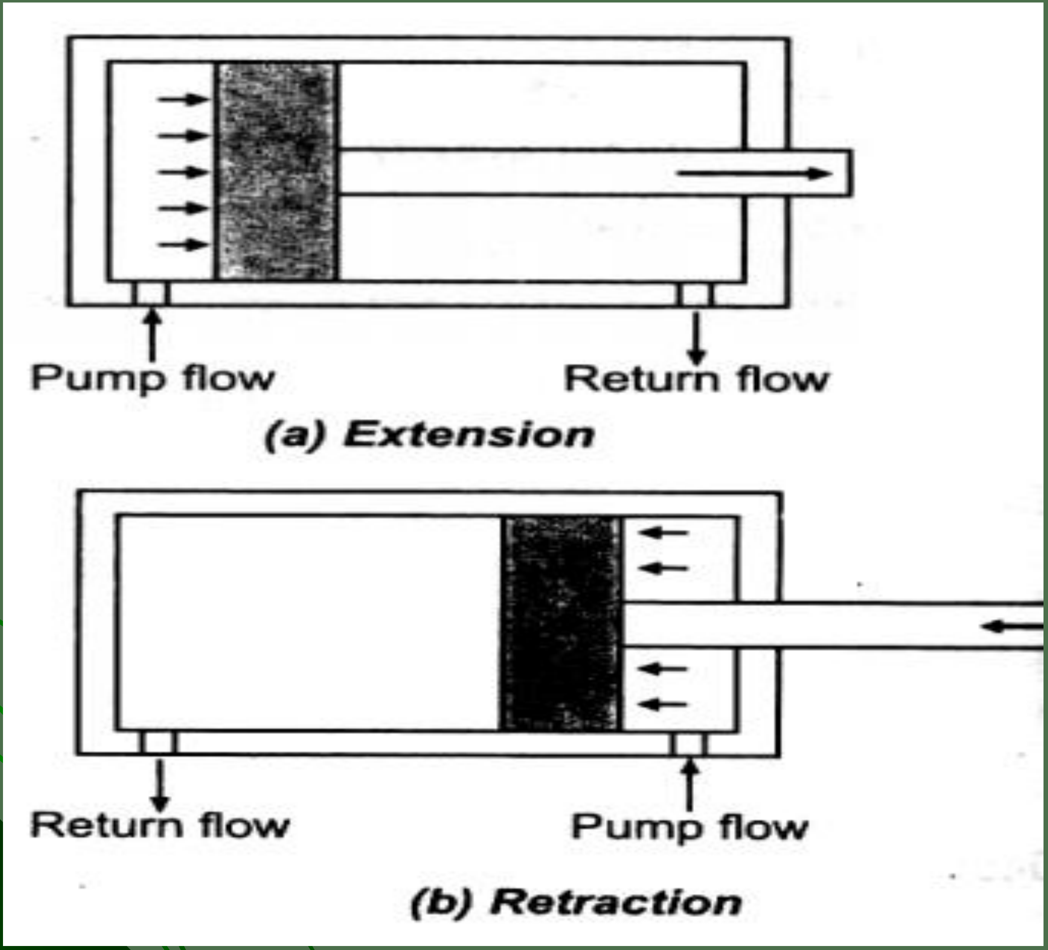


DOUBLE ACTING CYLINDER

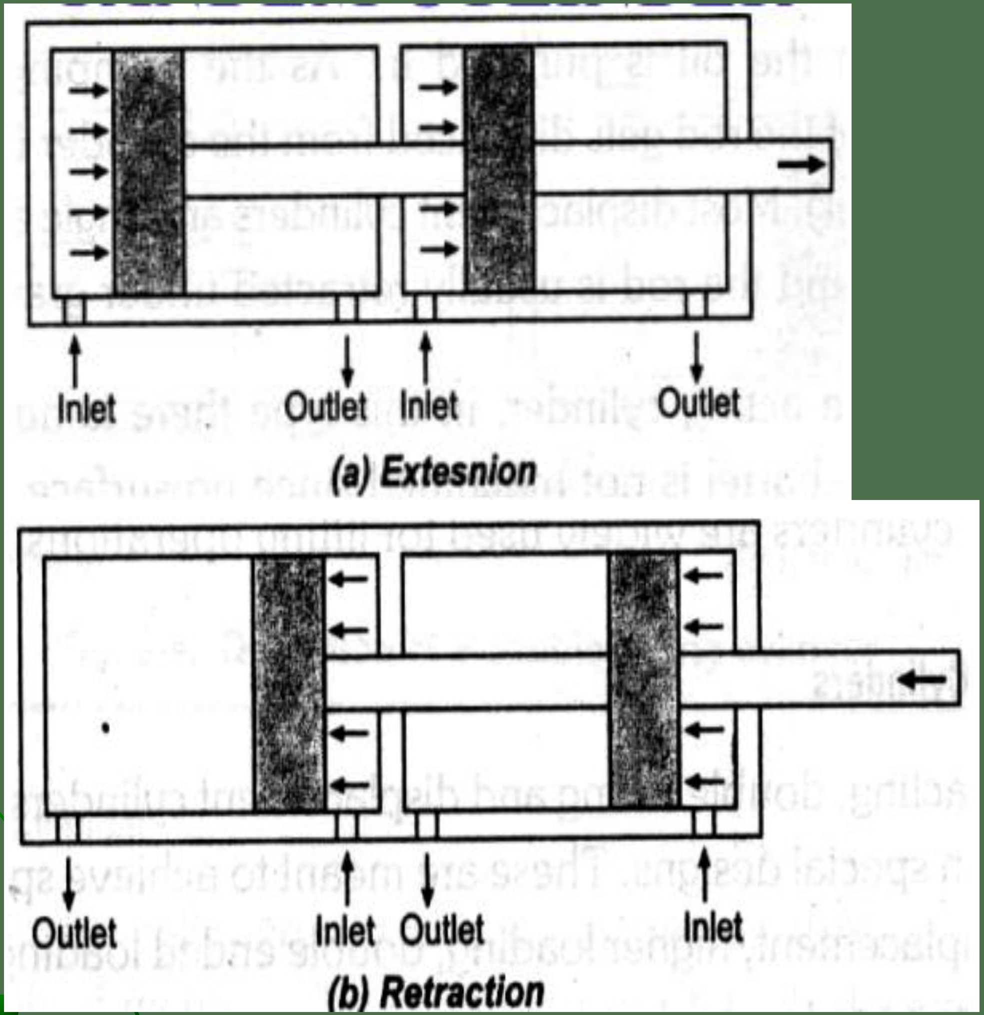


Double-acting cylinder

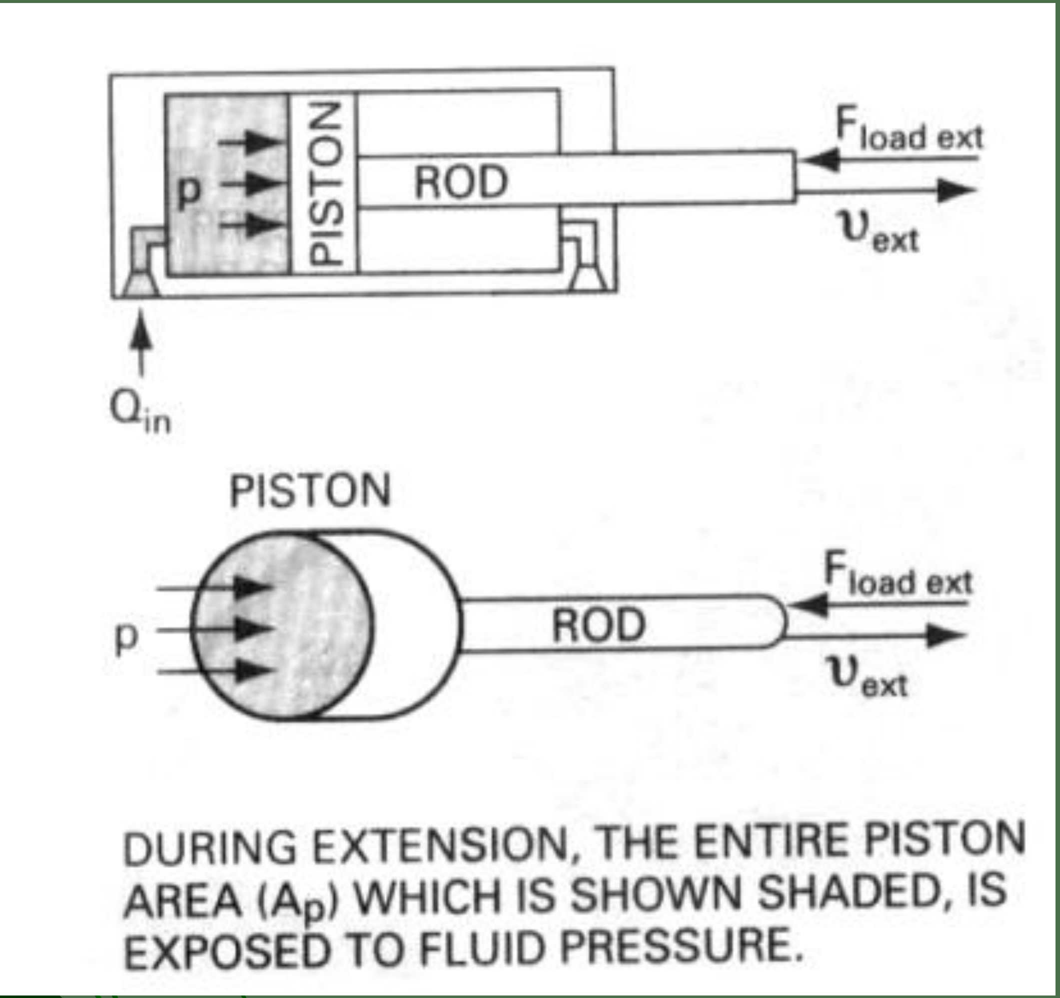
DOUBLE ACTING CYLINDER OPERATION



TANDEM CYLINDER



CYLINDER FORCE, VELOCITY AND POWER



Continued…….

The output force (F) & piston velocity (υ) of double acting cylinders are not same for extension & retraction strokes

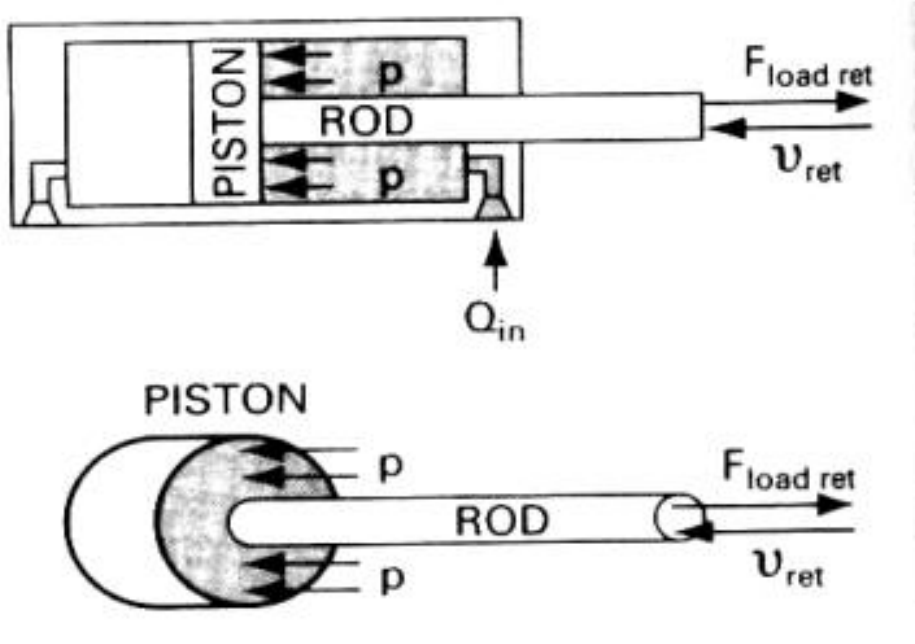
EXTENSION STROKE

Fluid enters the blank end of cylinder through the entire circular area of the piston A_p

$$F_{ext}(\mathrm{N}) = p\,(\mathrm{Pa}) \times A_p(\mathrm{m}^2)$$

$$v_{ext}(\mathrm{m/s}) = \frac{Q_{in}(\mathrm{m}^3/\mathrm{s})}{A_p(\mathrm{m}^2)}$$

Continued…….



DURING RETRACTION, ONLY THE ANNULAR AREA AROUND THE ROD (A_p-A_r) WHICH IS SHOWN SHADED, IS EXPOSED TO FLUID PRESSURE.

Continued…….

RETRACTION STROKE

Fluid enters the rod end of cylinder through the Smaller annular between the rod & cylinder bore "A_p- A_r"

$$F_{ret}(\mathrm{N}) = p\,(\mathrm{Pa}) \times (A_p - A_r)\mathrm{m}^2$$

$$v_{ret}(\mathrm{m/s}) = \frac{Q_{in}(\mathrm{m}^3/\mathrm{s})}{(A_p - A_r)\mathrm{m}^2}$$

Extension force is greater than the retraction force for the same operating pressure

Retraction velocity is greater the extension velocity for the same input flow rate

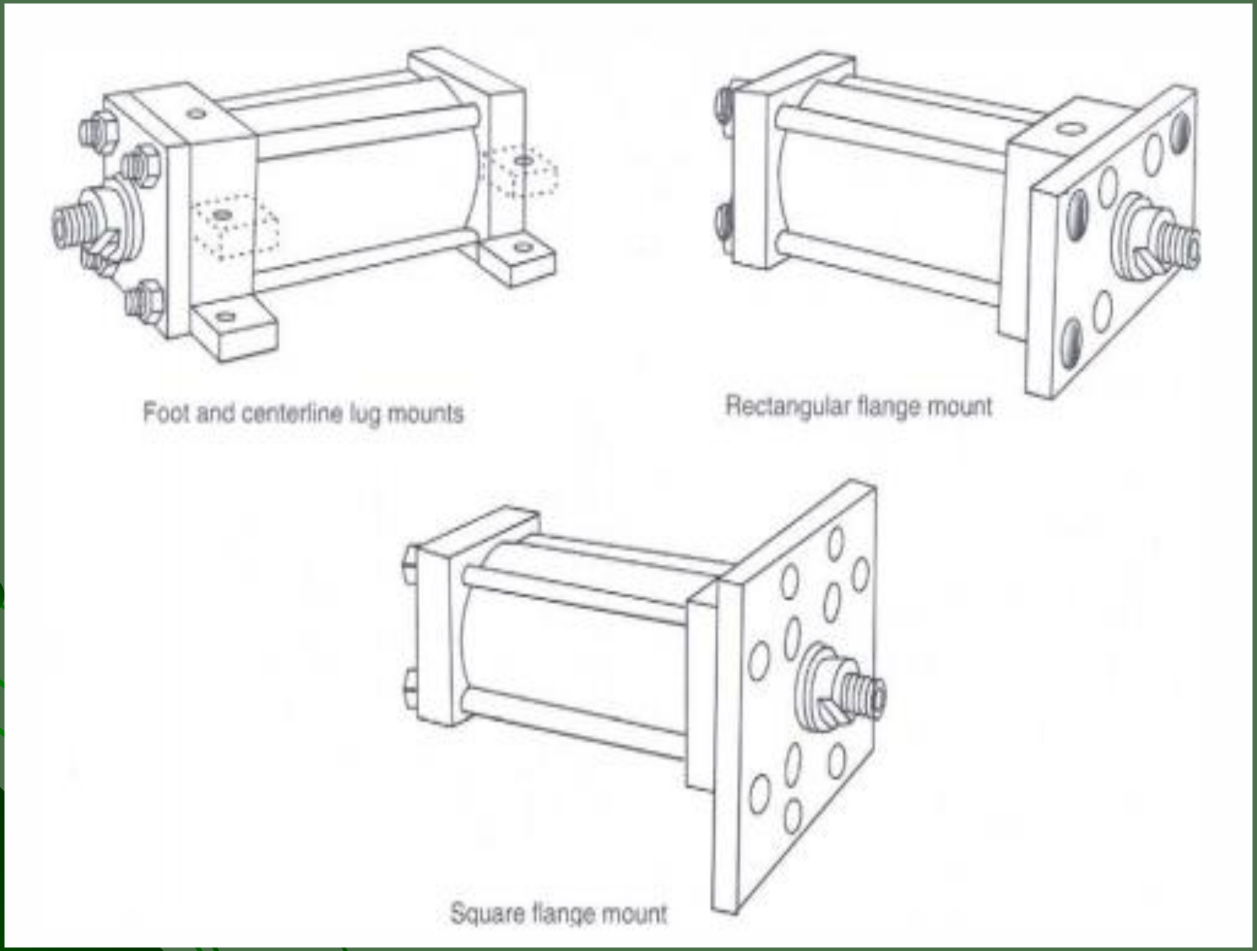
Continued…….

The power developed by a hydraulic cylinder equals the product of its force and velocity during a given stroke

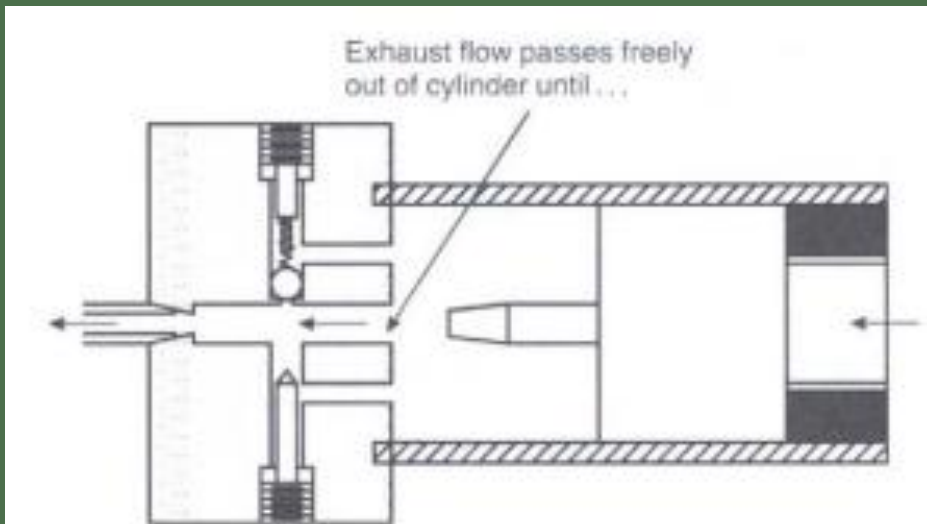
$$\text{Power (KW)} = F\ (kN) \times V_p\ (m/s)$$

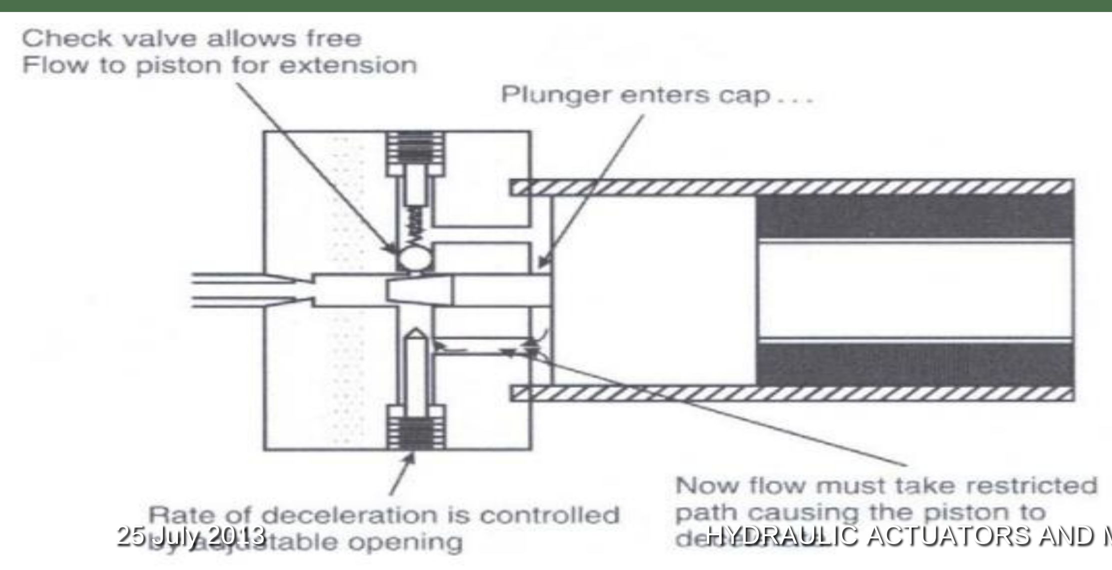
$$= Q_{in}\ (m^3/s) \times P\ (kPa)$$

CYLINDER MOUNTINGS



HYDRAULIC CYLINDER CUSHIONS





- A pump supplies oil at 0.0016 cubic meter per second to a 40 mm diameter double acting hydraulic cylinder. If the load is 5000 N (extending and retracting) and rod diameter is 20 mm find the
- Hydraulic pressure during the extending stroke
- Piston velocity during the extending stroke
- Cylinder KW power during the extending stroke
- Hydraulic pressure during retracting stroke
- Piston velocity during the retraction stroke
- Cylinder KW power during the retraction stroke

UNIT – 3

CONTROL COMPONENTS IN HYDRAULIC SYSTEM

HYDRAULIC VALVE

- Fluid power is controlled primarily through the use of control devices called *hydraulic valves*.

Types of Valves

- 1. Directional control valves
- 2. Pressure control valves
- 3. Flow control valves

DIRECTIONAL CONTROL VALVES

- Direction control valves are used to control the direction of flow in a hydraulic circuit.
- They are used to extend, retract, position or reciprocate hydraulic cylinder and other components for linear motion.
- Valves contains ports that are external openings for fluid to enter and leave via connecting pipelines.
- The number of ports on a directional control valve (DCV) is usually identified by the term **" way".** For example, a valve with four ports is named as **four-way valve.**

Classification of direction control valves

- **According to type of construction** :
- Poppet valves
- Spool valves
- **According to number of working ports :**
- Two- way valves
- Three – way valves
- Four- way valves.

Classification of direction control valve

- **According to number of Switching position:**
- Two – position
- Three - position
- **According to Actuating mechanism:**
- Manual actuation
- Mechanical actuation
- Solenoid (Electrical) actuation
- Hydraulic (Pilot) actuation
- Pneumatic actuation
- Indirect actuation

Designation of direction control valves

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

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

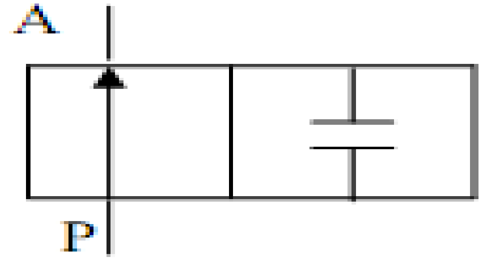


Fig 4.1. 2 /2 valve symbol

2/3 way valve

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

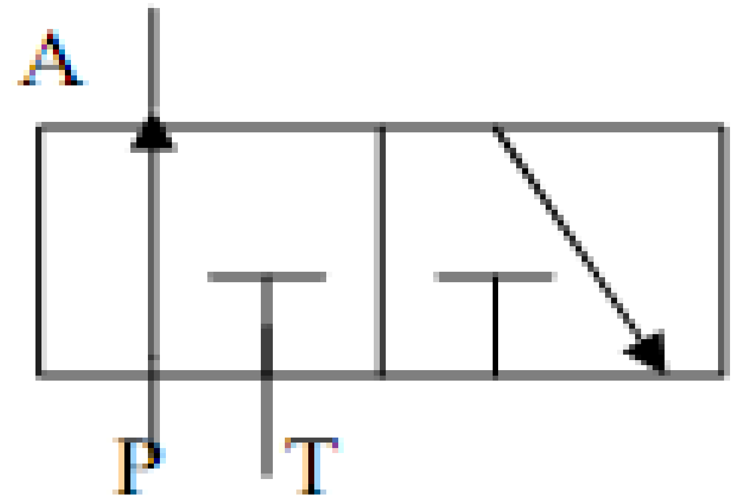


Fig 4.2. 2 / 3 valve symbol

2/4 way valve

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

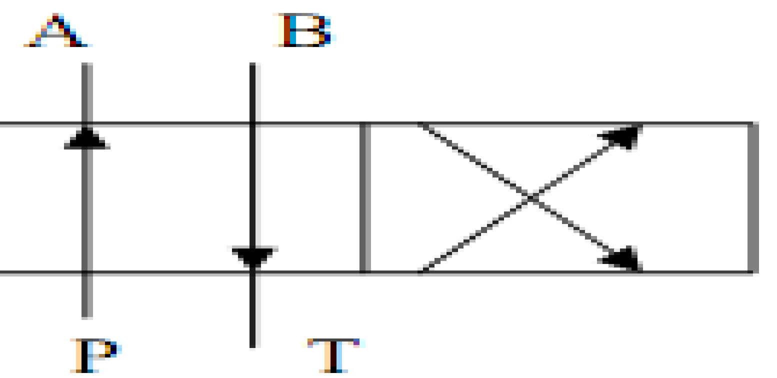


Fig 4.3. 2 / 4 valve symbol

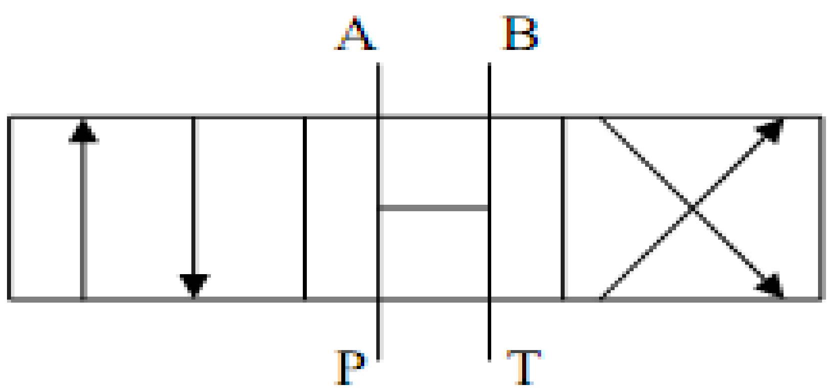


Fig 4.4. 3/ 4 valve symbol :

A valv… 3 Switching position… valve. Fig 4 shows a… position

POPPET VALVE (CHECK VALVE)

2 / 2 DCV (Poppet design) :-

a. Valve Closed

b. Valve Opened

Fig 4.6. 2 / 2 DCV Poppet Design

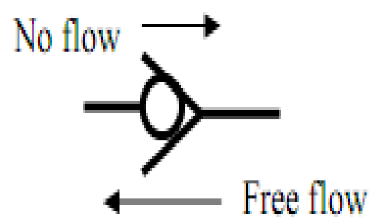


Fig 4.6c. Symbol of 2/2 poppet valve (Check valve)

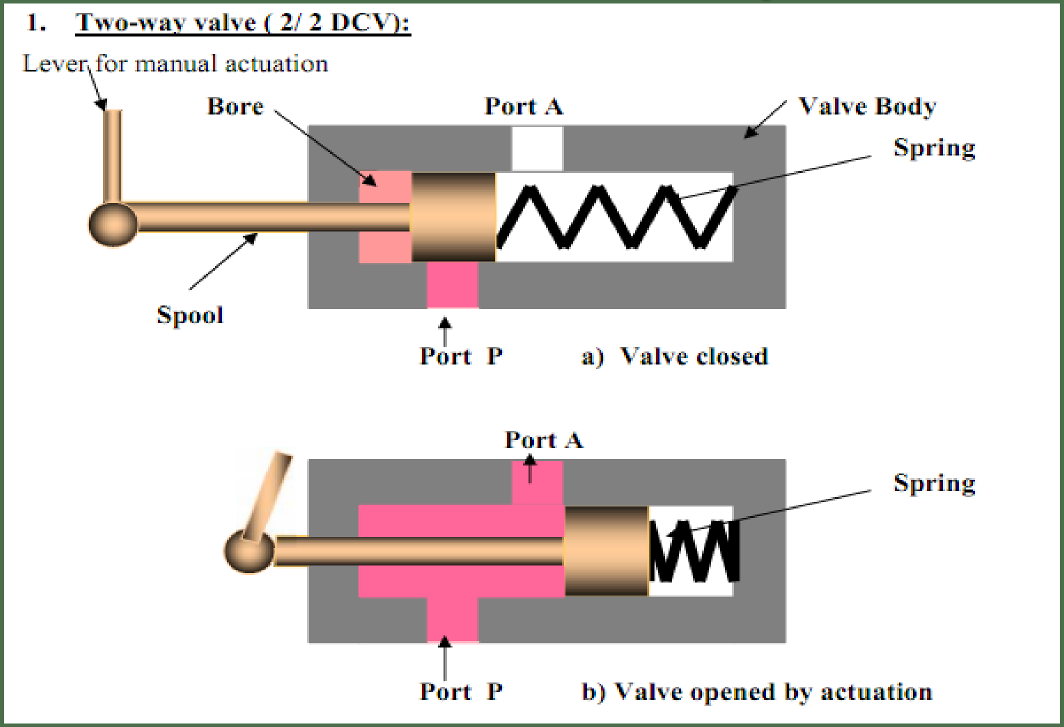
Advantages and disadvantages

- **Advantages of these valves are;**
- No Leakage as it provides absolute sealing.
- Long useful life, as there are no leakage of oil flows.
- May be used with even the highest pressures, as no hydraulic sticking (pressure dependent deformation) and leakages occurs in the valve.
- **The disadvantages of these valves are;**
- Large pressure losses due to short strokes
- Pressure collapse during switching phase due to negative overlap (connection of pump, actuator and tank at the same time

SPOOL VALVE

- The spool valve consists of a spool which is a cylindrical member that has large-diameter lands machined to slide in a very close- fitting bore of the valve body. The spool valves are sealed along the clearance between the moving spool and the housing. The degree of sealing depends on the size of the gap, the viscosity of the fluid and especially on the level of pressure.

TWO WAY VALVE (2/2 DCV)



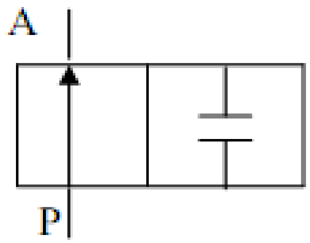


Fig 4.1. 2 /2 valve symbol

3 way DCV

- Generally, these valves are used to operate single-acting cylinders.
- Three-way directional valves are available for manual, mechanical, pilot, solenoid actuation. These valves may be two-position, or three -position.
- These valves are normally closed valves (i.e. the pump port is blocked when the valve is not operating). The three-way valve ports are inlet from the pump, working ports , and exhaust to tank.
- These ports are generally identified as follows : P= pressure(Pump)port ; A or B = working port and T = tank port.

2/3 DIRECTION CONTROL VALVE

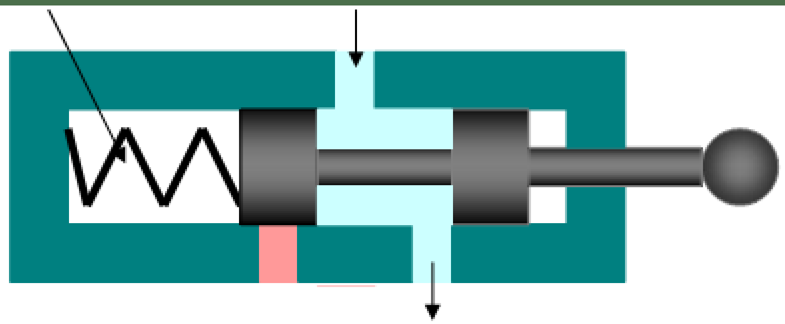
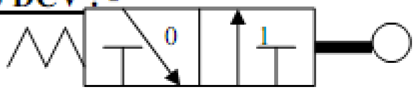


Fig 4.8 2 /3 DCV

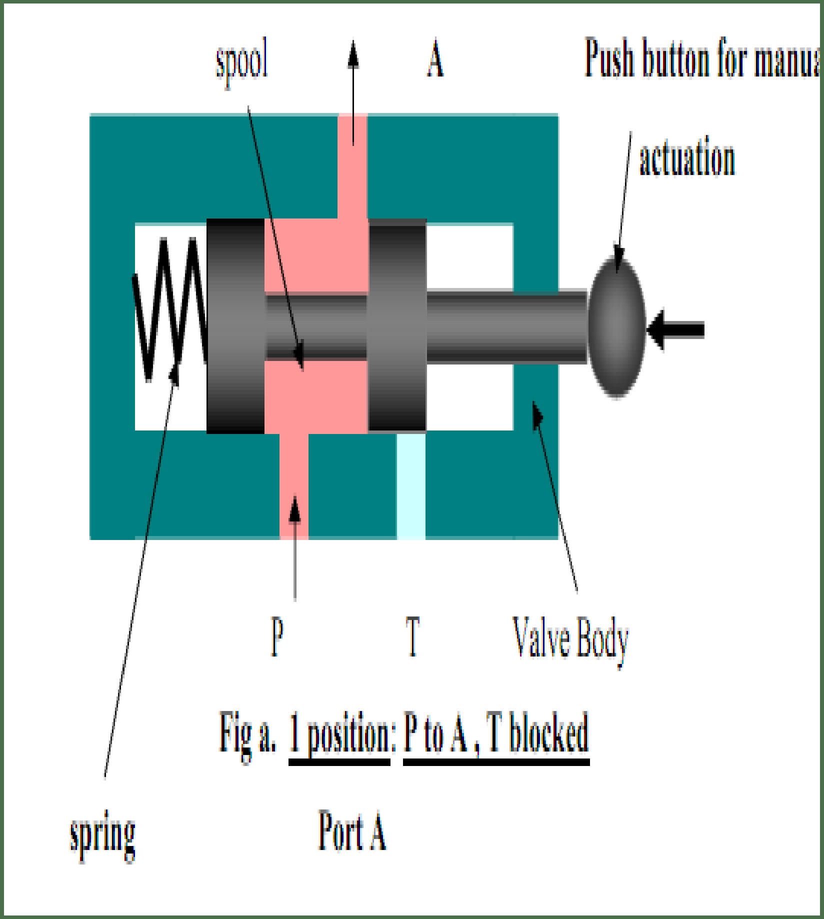
Symbol 2/ 3 DCV : -



Spool Position 1 & 0

.Spool position 1: When the valve is actuated, the spool moves towards left . In this position flow from pump enters the valve port P and flows out through the port A as shown by the straight- through line and arrow (fig a). In this position, port T is blocked by the spool.

Spool position 0: when the valve is un-actuated by the absence of hand force, the valve assumes this



4 way DCV

- These valves are generally used to operate cylinders and fluid motors in both directions hydraulically.
- The four ways are Port P that is connected to pump, tank port T, and two working ports A and B connected to the actuator.
- These valves are available with a choice of actuation, manual, mechanical, solenoid, pilot & pneumatic.

Three position Four way valve

- Three switching position
- 4 ways or ports
- P - connected to pump
- T - connected to tank
- A - connected to left end of double acting cylinder.
- B - connected to right end of cylinder

Working principle of 4/3 way valve

- When left end of the valve is actuated P is connected to working port A and working port B is connected to T.
- When right end of the valve is actuated P is connected to B and A is connected to T.
- When valve is un – actuated it will be at center position due to the balancing opposing spring forces.

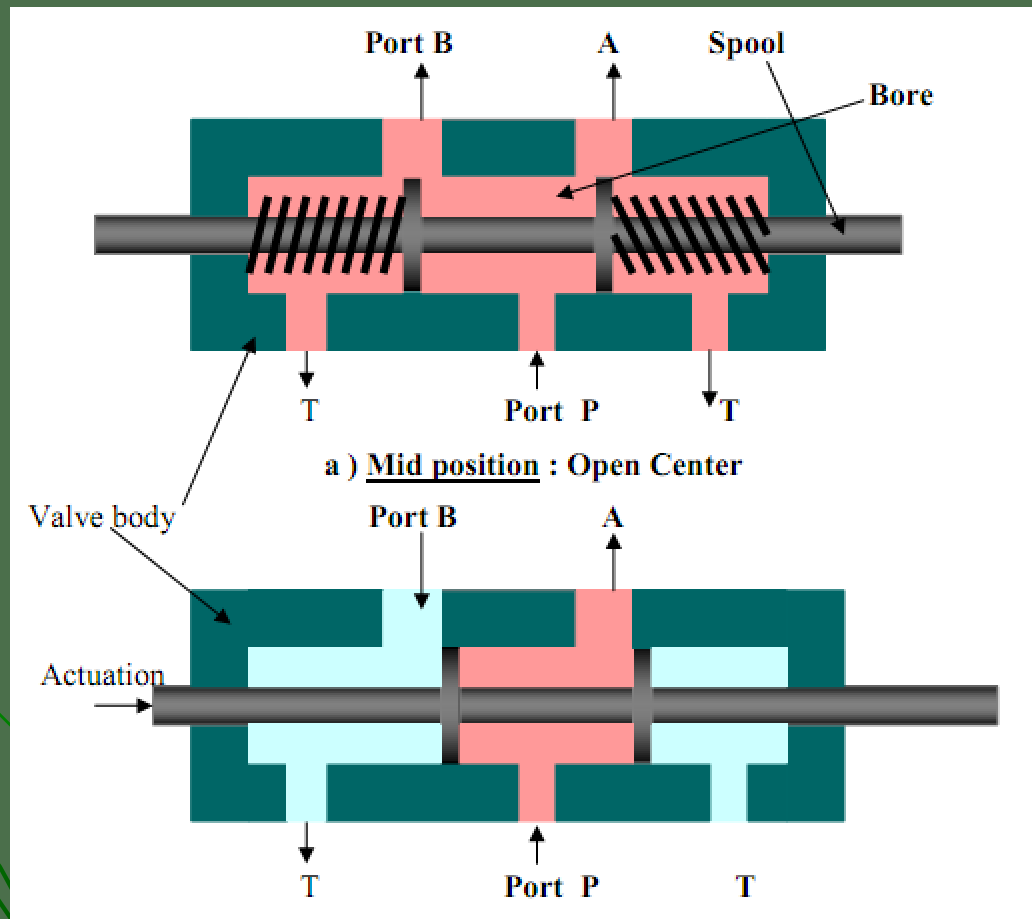
Centre configuration of 3/4 way direction control valve

- ***Open center***
- ***Closed center***
- ***Tandem center***
- ***Floating center***
- ***Regenerative center with open, closed and tandem.***

Open center (mid position)

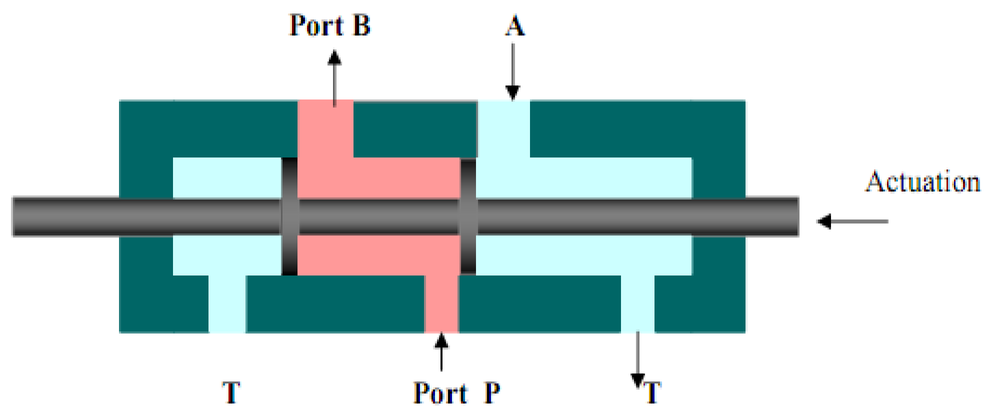
- All ports are open to each other in the center position.
- Pump flow is directed to the tank at atmospheric pressure.
- At the same time actuator can be moved freely by applying an external force.
- No work can be done by any part of the system as long as the valve remains at the center, since the fluid always follows path of least resistance.
- This means that other auxiliary device cannot function using pressure energy.

Open center (mid position)



b) 1 Position , Flow : P to A & B to T

Open center



c) 2 position : Flow : P to B & A to T

Fig 4.9 (a, b, c): 3 position- 4 way , open centered DCV

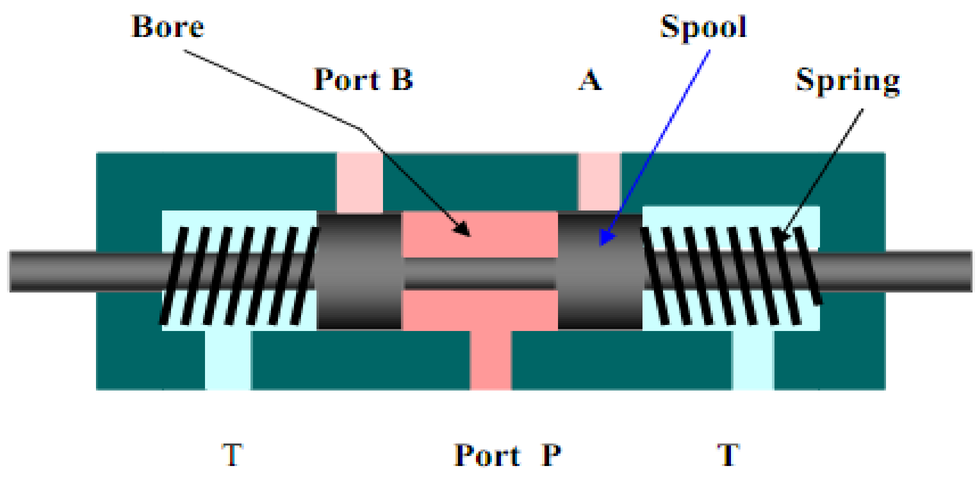
(Note : In Fig b & c spring not shown)

Closed center

- All ports are closed to each other.
- Hence actuator connected to port A and B hydraulically locked cannot be moved by an external force.
- The pump flow must go over the pressure relief valve.
- It wastes pump power, increase wear and shorten pump life.

Closed center

b.) Closed Center 3 / 4 DCV :



Mid Position: Closed Center

Fig 4. 10a. Closed Center 3 / 4 DCV

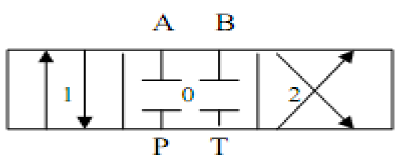


Fig 4.10b. Symbol

Tandem center

- The working ports A and B are blocked.
- Pump port p is connected to tank port T.
- It unloads the pump at atmospheric pressure.
- Application of this type of centre configuration is to hold a cylinder or hydraulic motor under load.
- To permit the pump flow to series of valves in multiple circuitry.

Tandem center 3/4 way valve

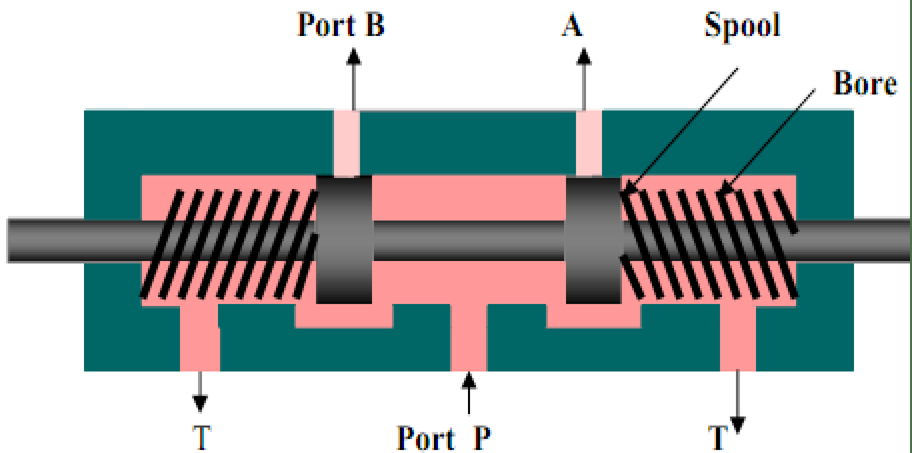


Fig 4.11a. Tandem Center 3 / 4 DCV : Mid position

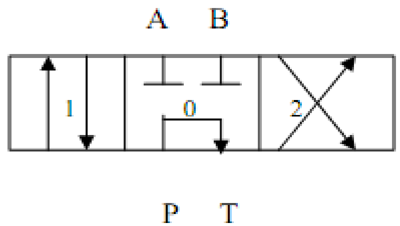


Fig 4.11b. Symbol

Regenerative centre

- Regenerative means the flow generated from system itself.
- This type of configuration is used whenever the actuator movement in one direction requires two different speeds.
- Part of length of extending stroke of actuator requiring fast movement during no load condition and remaining length slow controlled motion.
- During fast extending the DCV is un-actuated thereby by spring forces it comes to the mid position. This center saves on additional pump capacity required.

Double acting cylinder connected to regenerative center

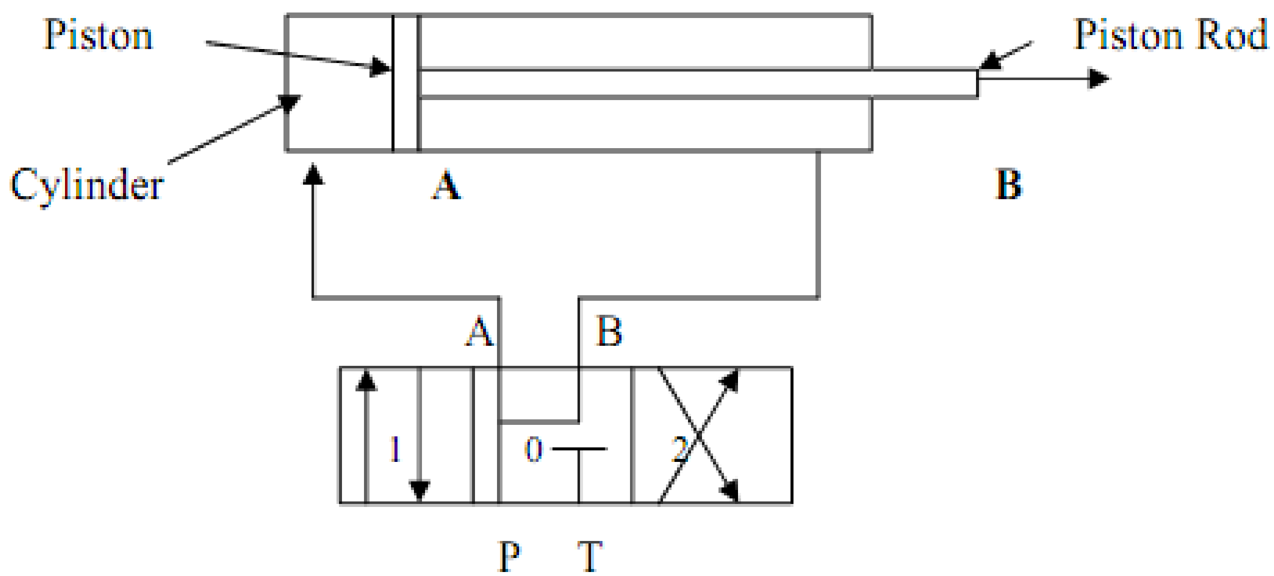
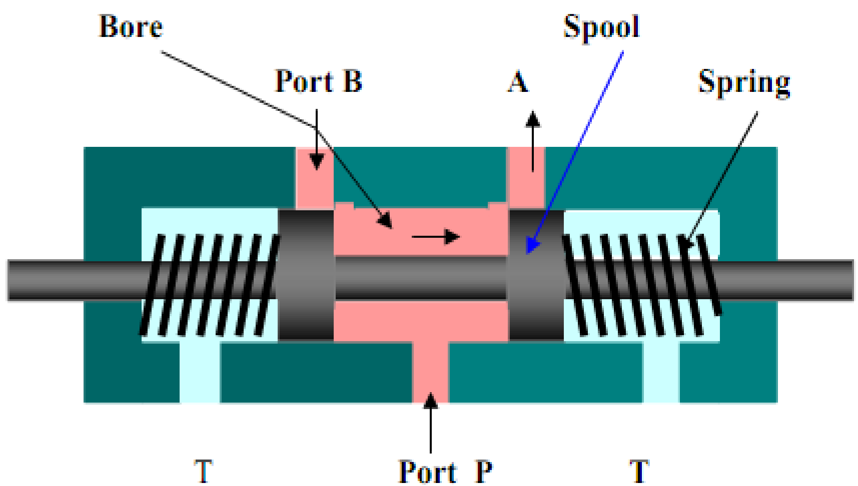


Fig 4.12 Double acting cylinder connected to Regenerative center 3 /4 DCV

Regenerative center 3/4 way valve



Mid Position

Fig 4. 13a. Regenerative Center 3 / 4 DCV

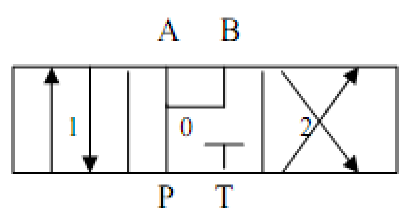
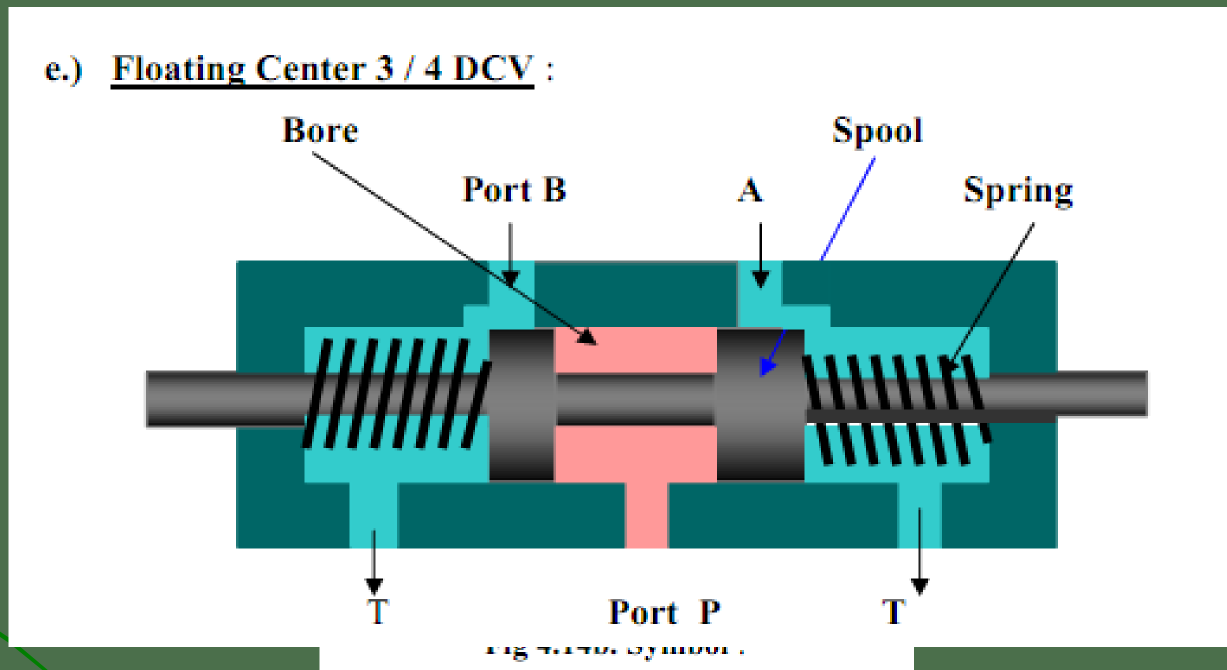


Fig 4.13b. Symbol

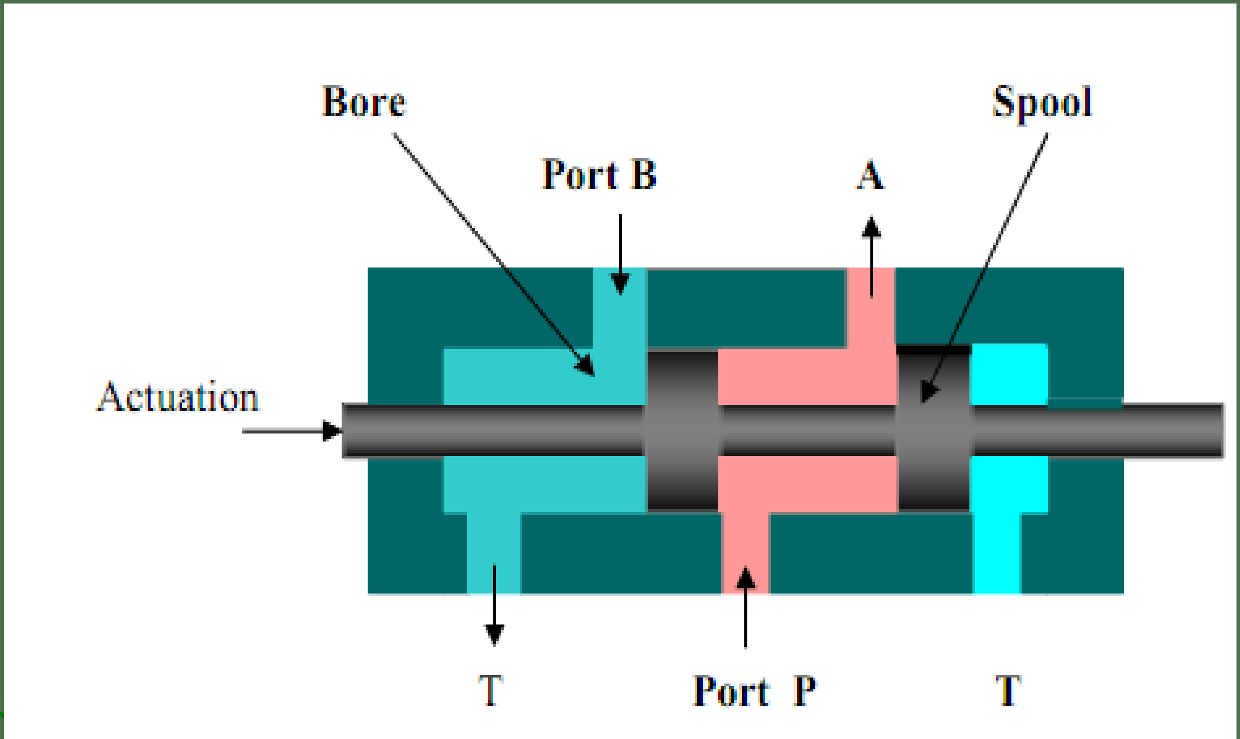
Floating center 3/4 way valve DCV

- In this position the pump port is blocked and the two working ports A and B are connected to tank port T.
- Since the working ports A and B are connected to tank T, the actuator can be moved freely without any external force and hence the name floating.
- In the mid position the pump flow must go over the relief valve when flow is not being used for any other parts of the circuit

Floating center 3/4 DCV

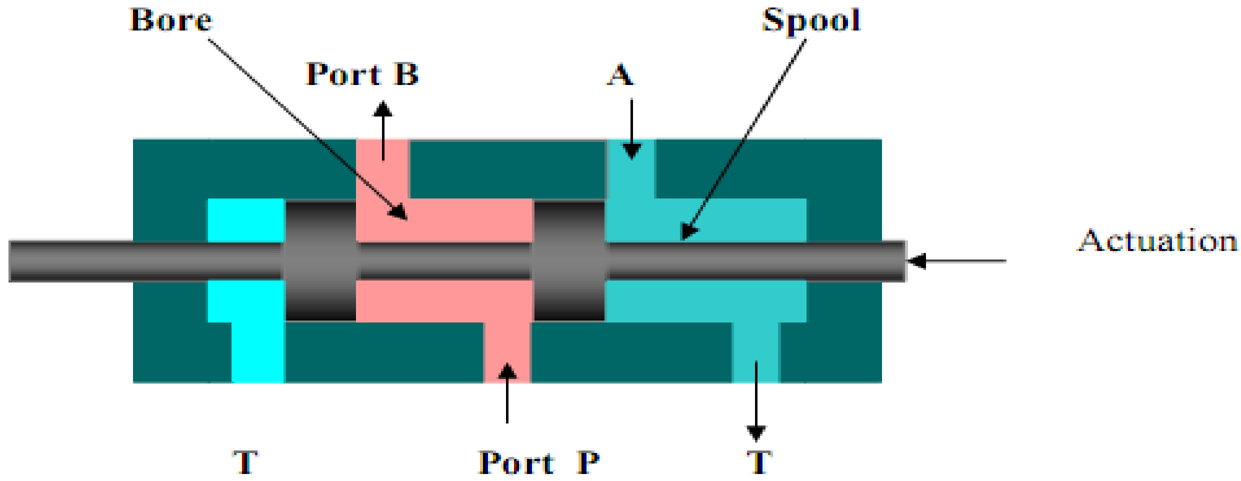


2/4 DCV



a. 1 Position : P to A and B to T

2/4 DCV



b. 2 Positon, P to B and A to T

Fig 4.15 : 2 / 4 DCV

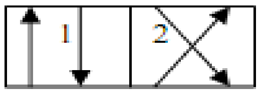


Fig 4.15c. Symbol

Actuation of direction control valves

Manually – actuated valve

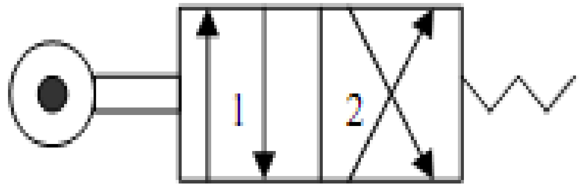
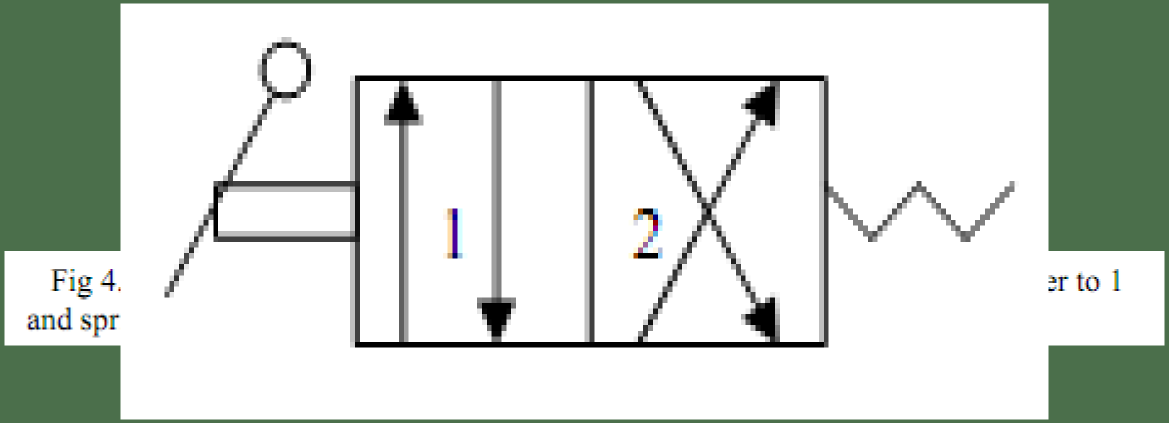


Fig 4.16.

Fig 4.16 shows the symbol of 2 / 4 DCV with manually operated by roller tappet to 1 and spring return to 2.

Actuation of DCV

Manually – actuated valve



Solenoid actuated

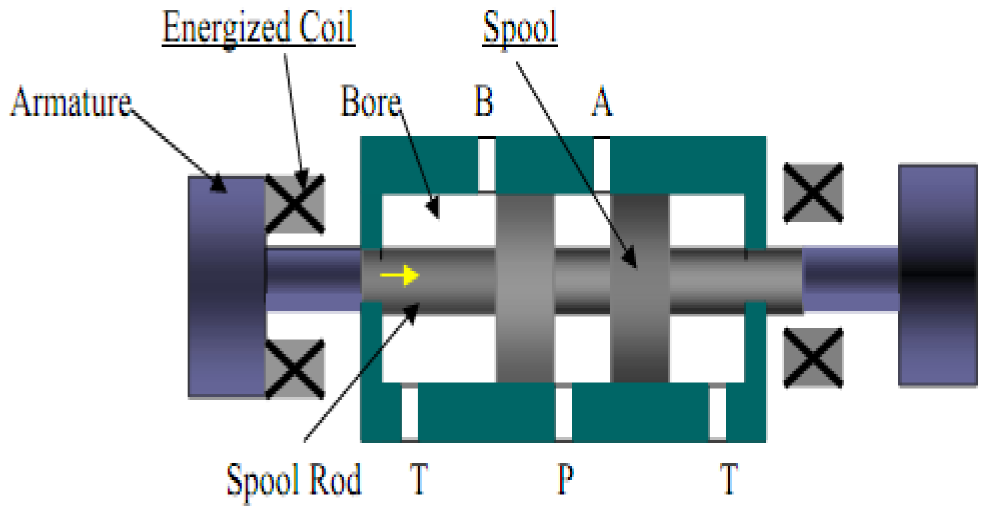


Fig 4.18 Working of solenoid to shift spool of valve.

Symbol for single and double solenoid actuated 2/4 way DCV

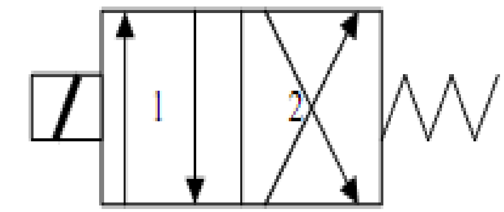


Fig 4.18 a) Symbol for Single solenoid-actuated , 2- Position, 4-way spring centered DCV

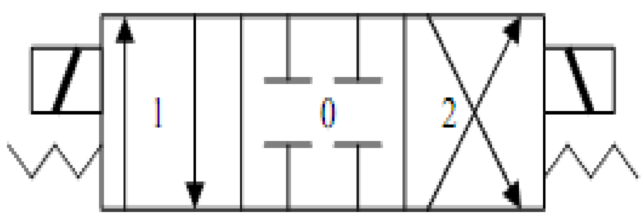
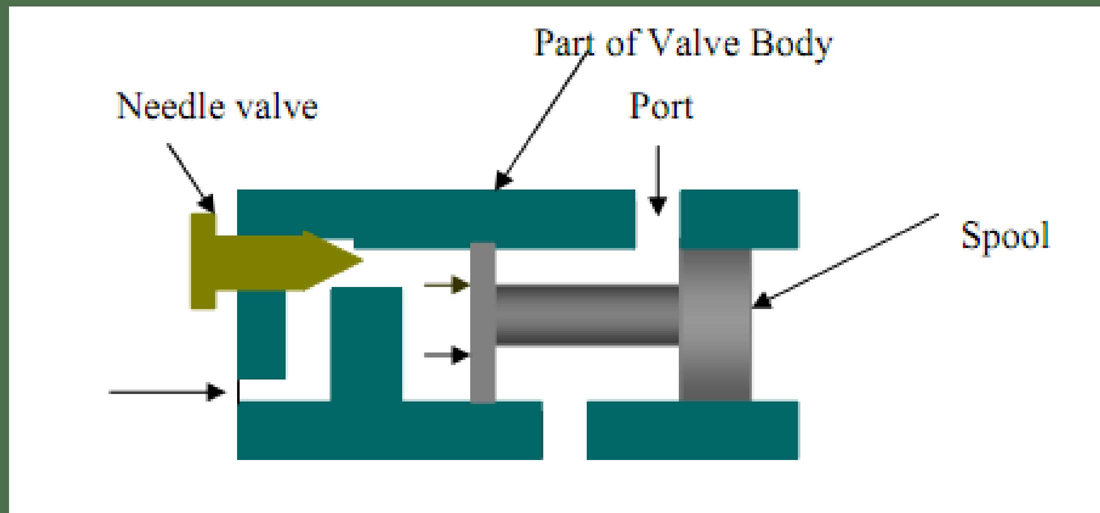


Fig 4.18 b) Symbol for Solenoid actuated, 3- position, , 4- way spring centered DCV

Hydraulic or pilot actuated valve



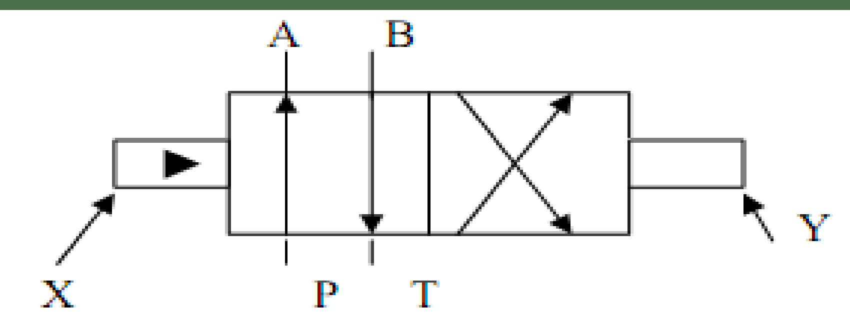


Fig 4.19b.. Symbol for pilot actuated 2 /4 DCV

Pneumatic actuation

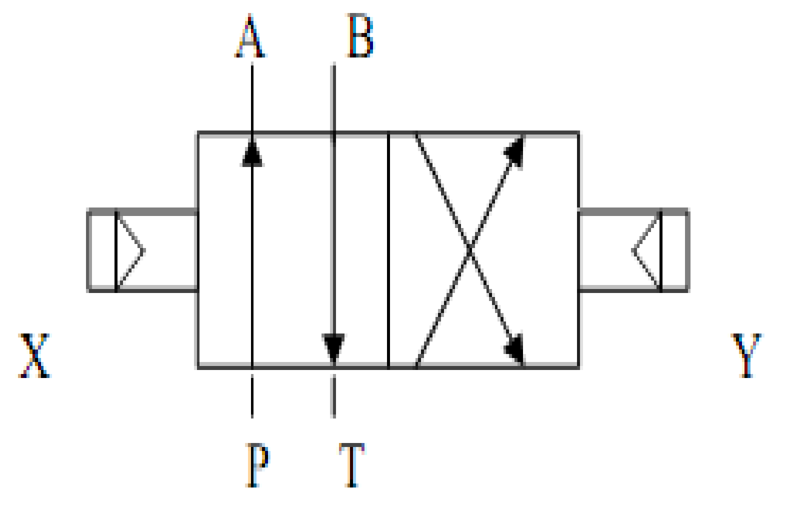


Fig 4.20. Symbol for Pneumatic actuated 2 / 4 DCV

Indirect actuation of DCV (electro – hydraulic)

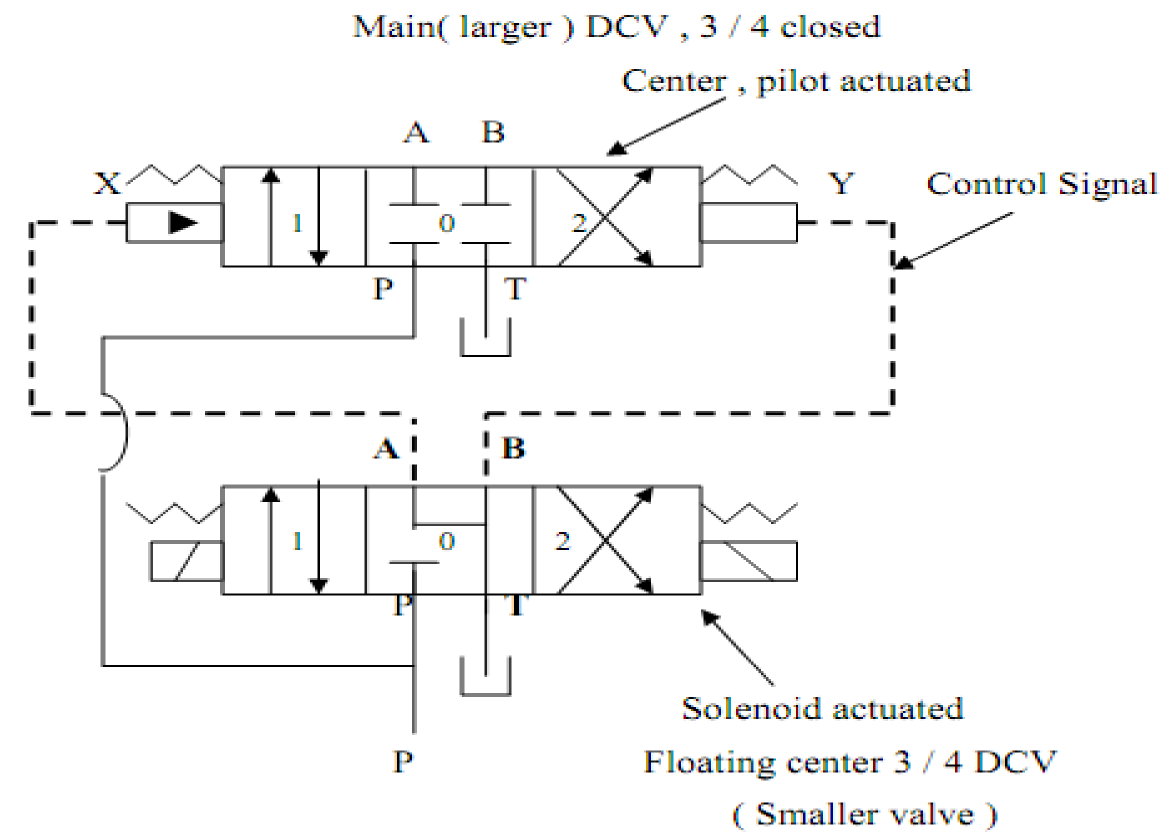


Fig 4.21a. Symbol for Indirect actuation
For 3 / 4 DCV

Symbol for indirect actuated closed center 3/4 way DCV

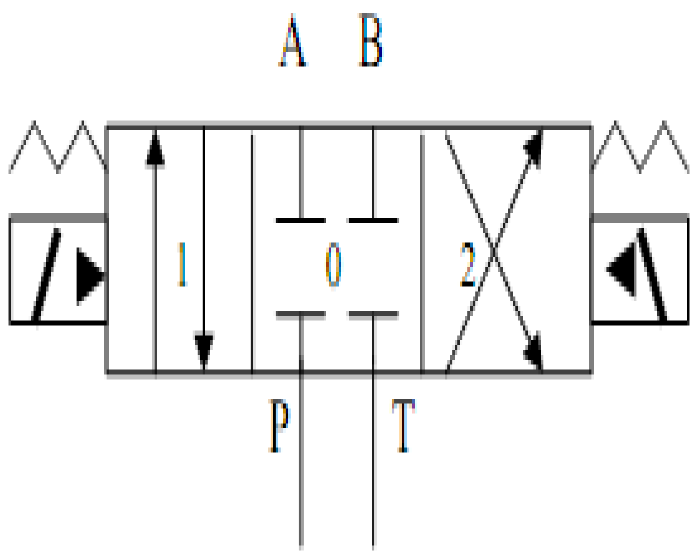
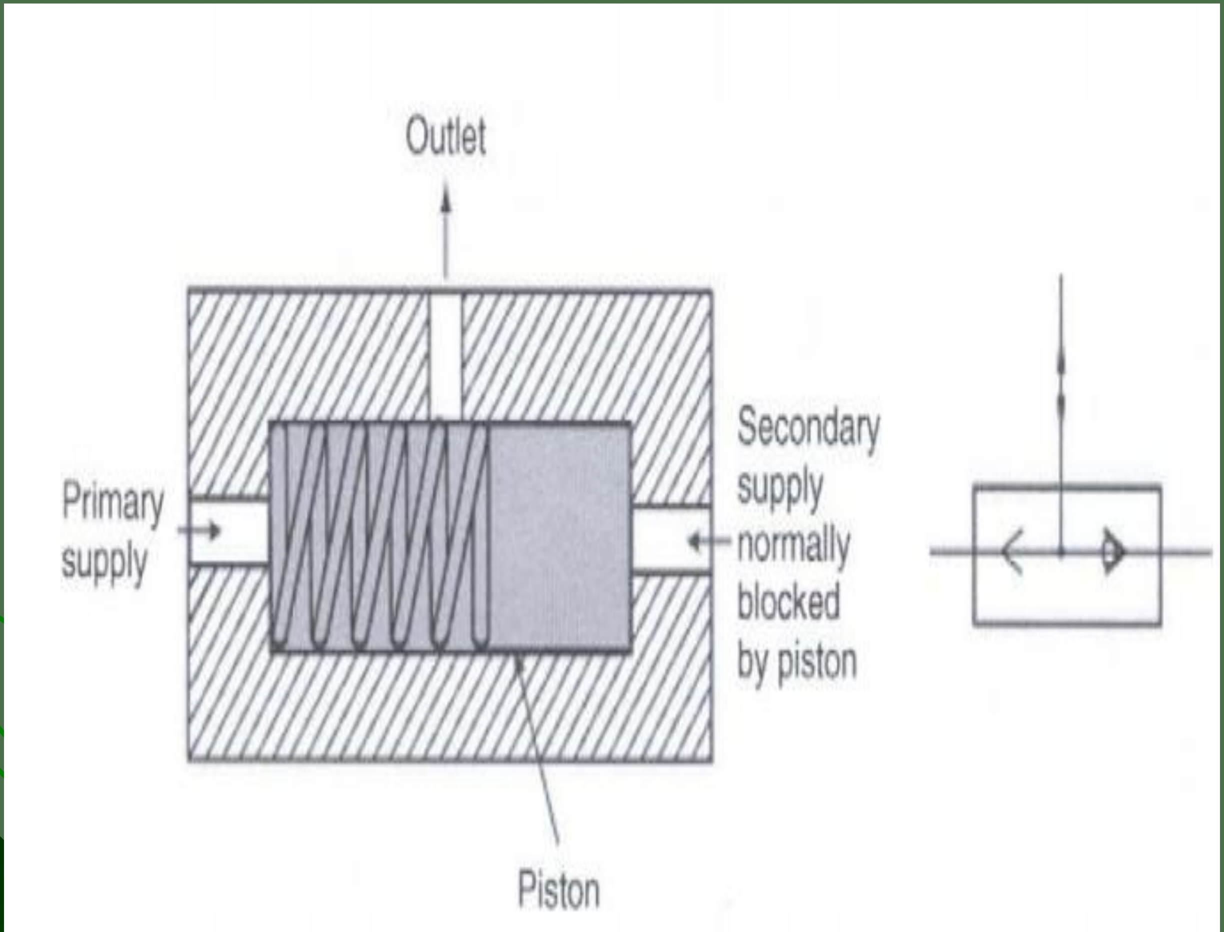


Fig 4.21b. Combined symbol :.Solenoid actuated internal pilot operated,

Shuttle valve



- *Pressure control valves*

- *Types of pressure control valve*

- *Direct operated type*
- *Pilot operated type*

Pressure relief valve

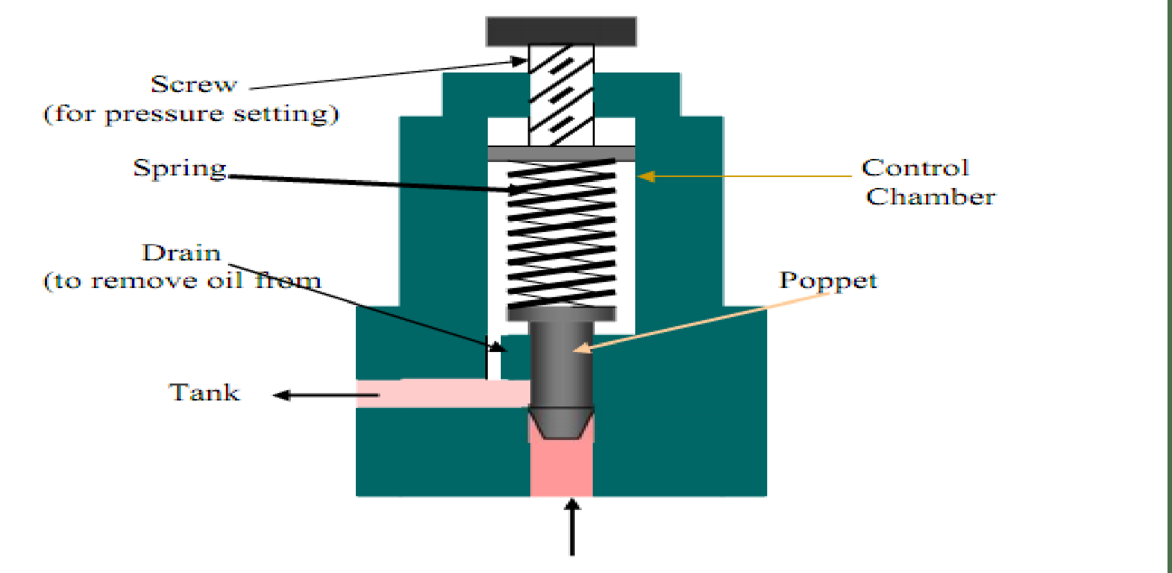


Fig 4.27a. **Pressure Relief Valve**

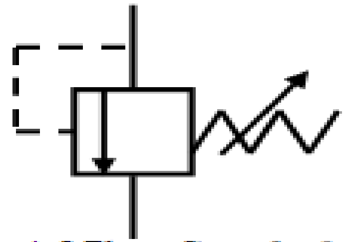
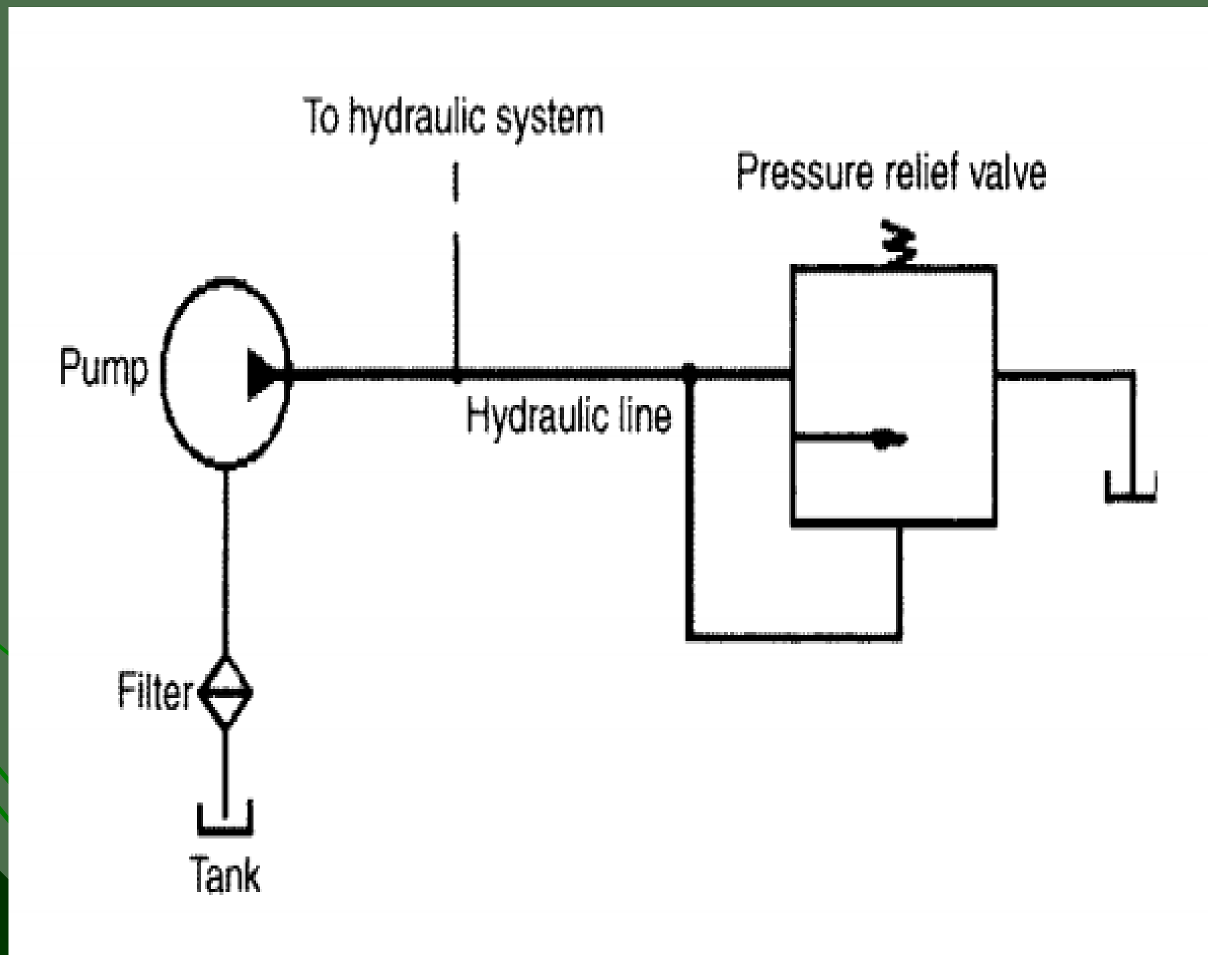


Fig 4.27b. **Symbol**

Partial hydraulic circuit showing relief valve



Pressure reducing valve

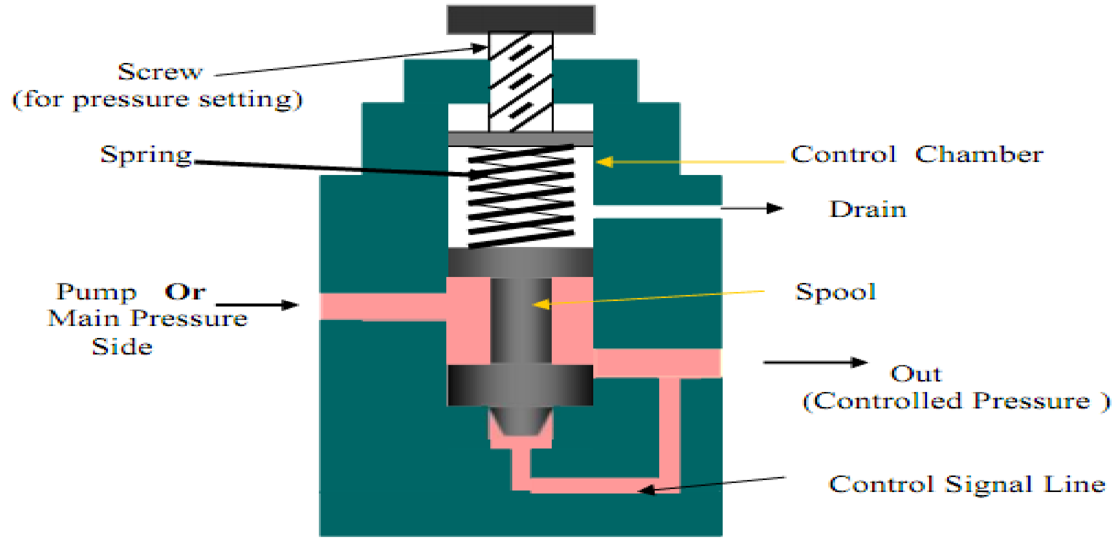


Fig 4.32a **Pressure Reducing Valve**

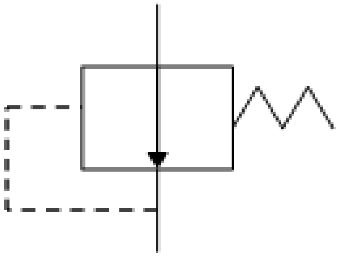
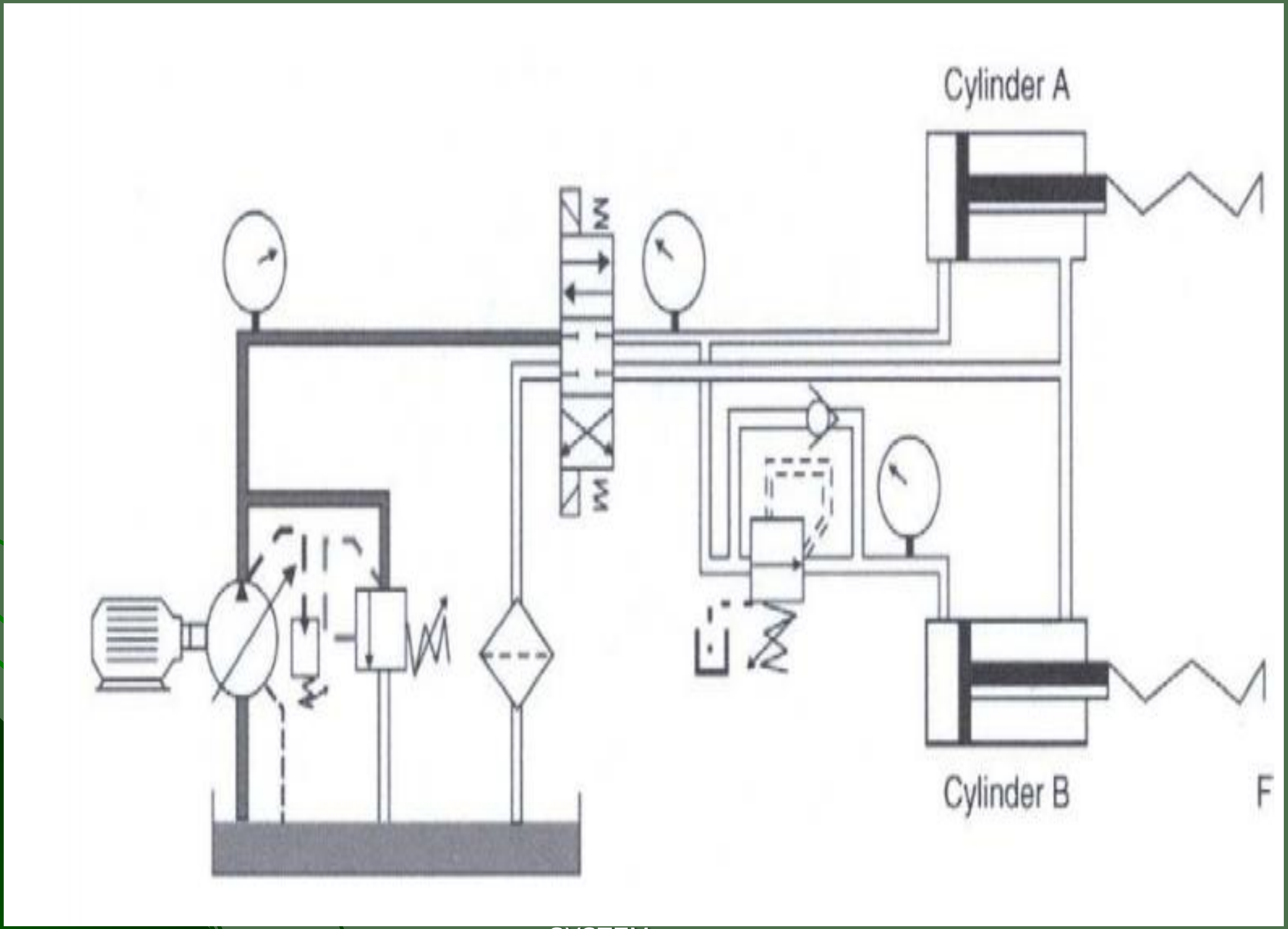


Fig 4.32b. **Symbol**

Application of pressure reducing valve



Unloading valve

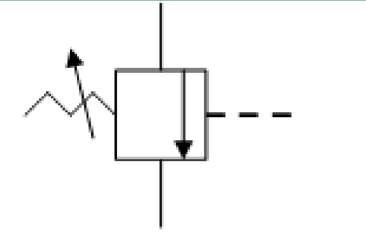
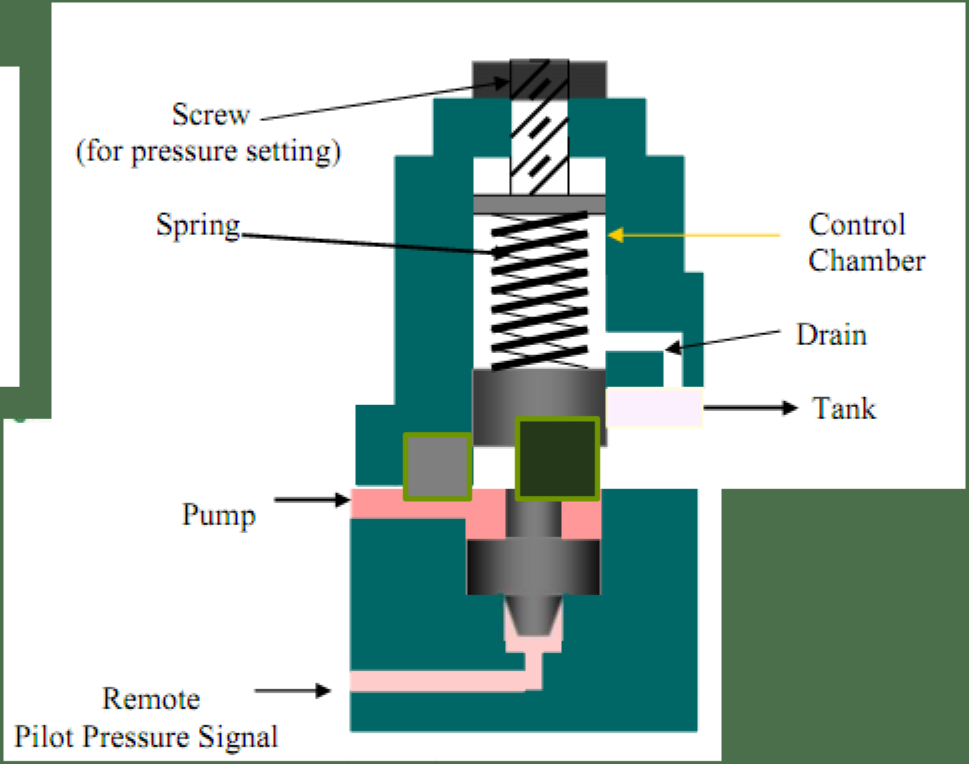
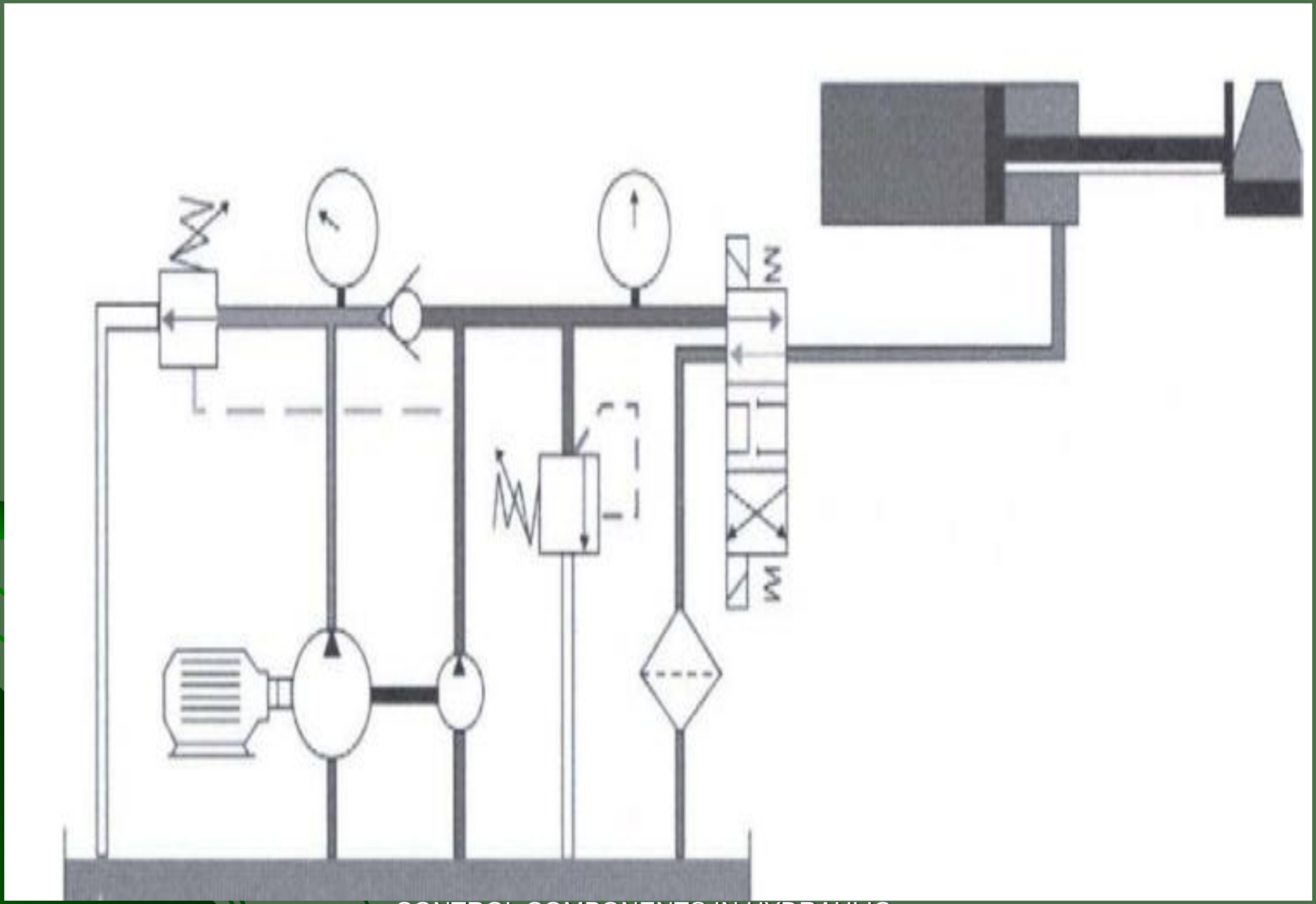


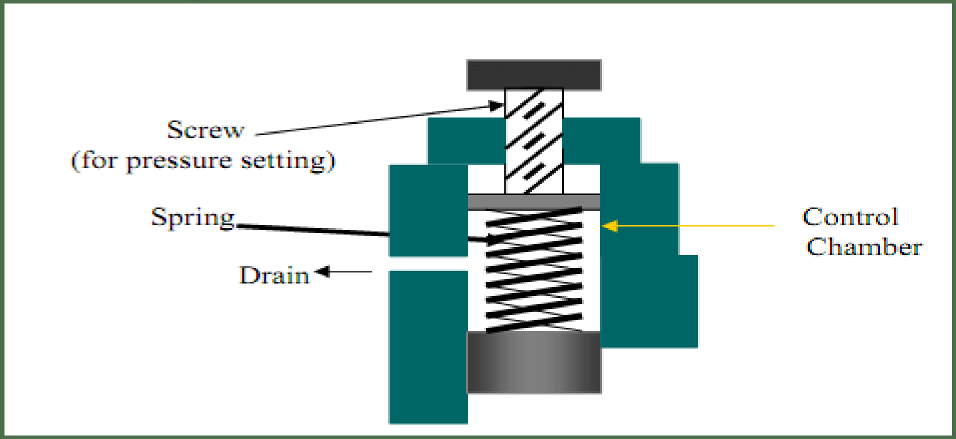
Fig 4.28a. **Symbol**



Application of unloading valve



Sequence valve



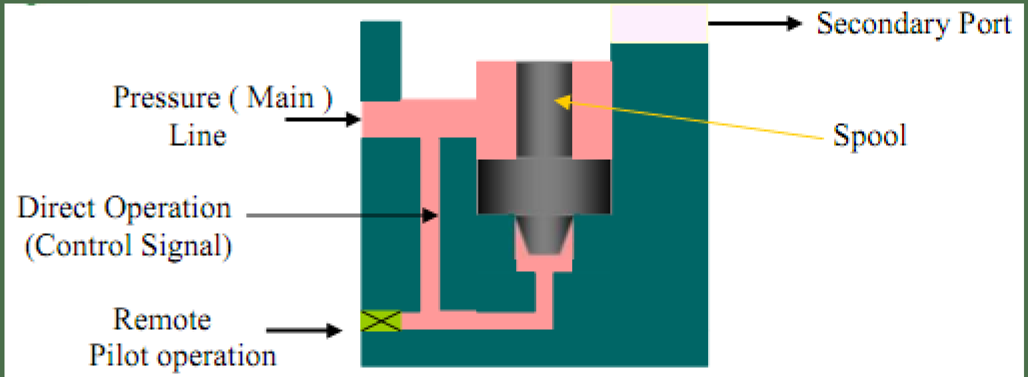
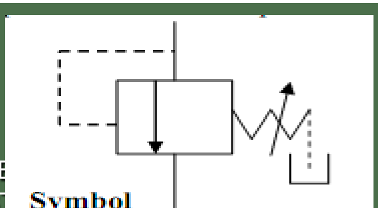
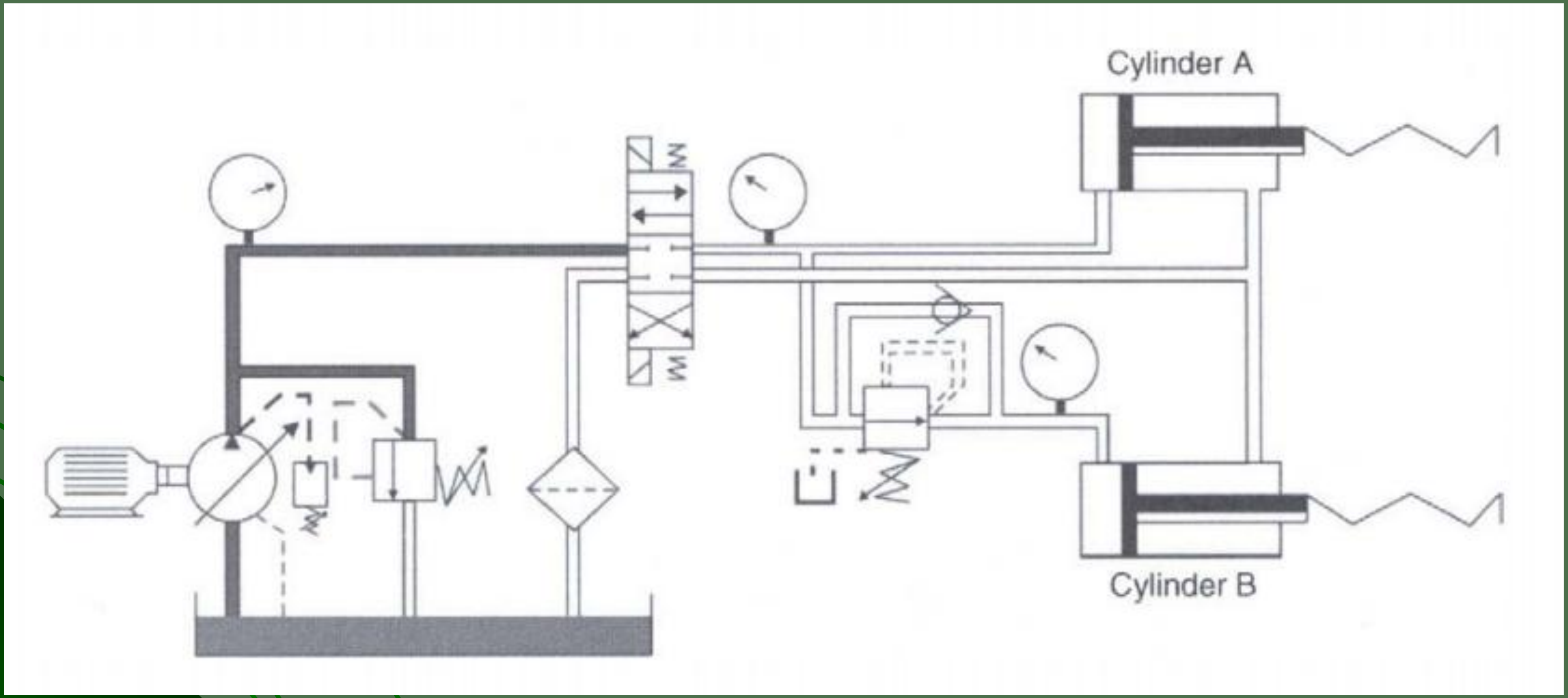


Fig 4.29b. **Sequence valve**

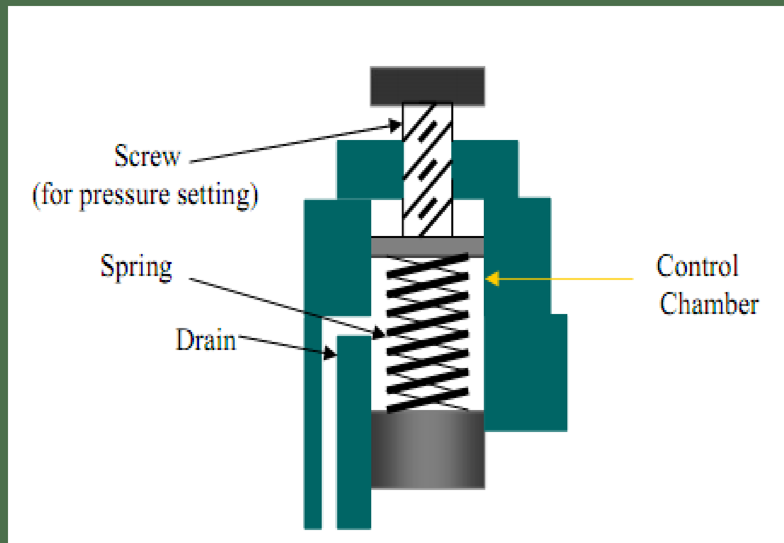


Symbol

Application of sequence valve



Counter balance valve



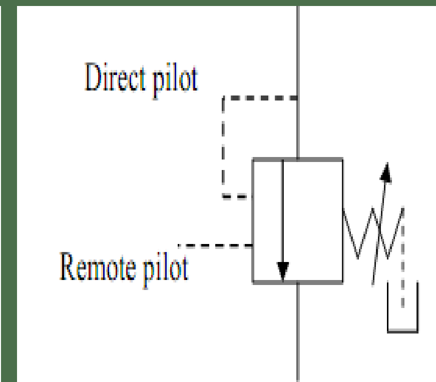
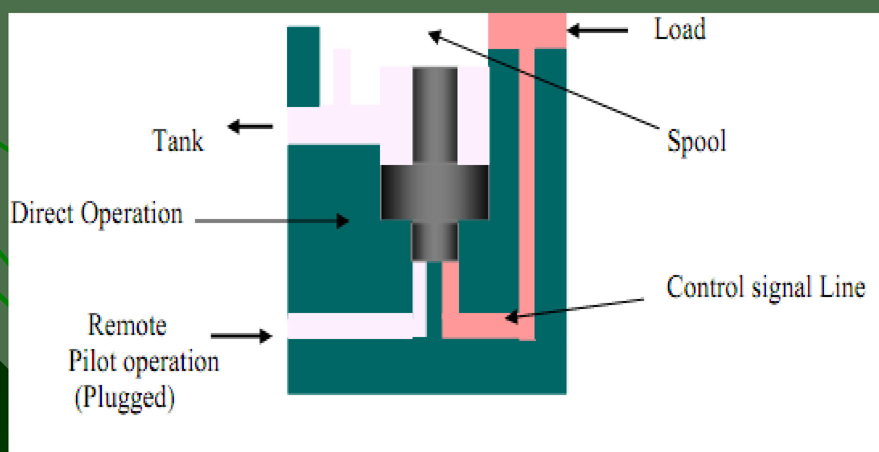
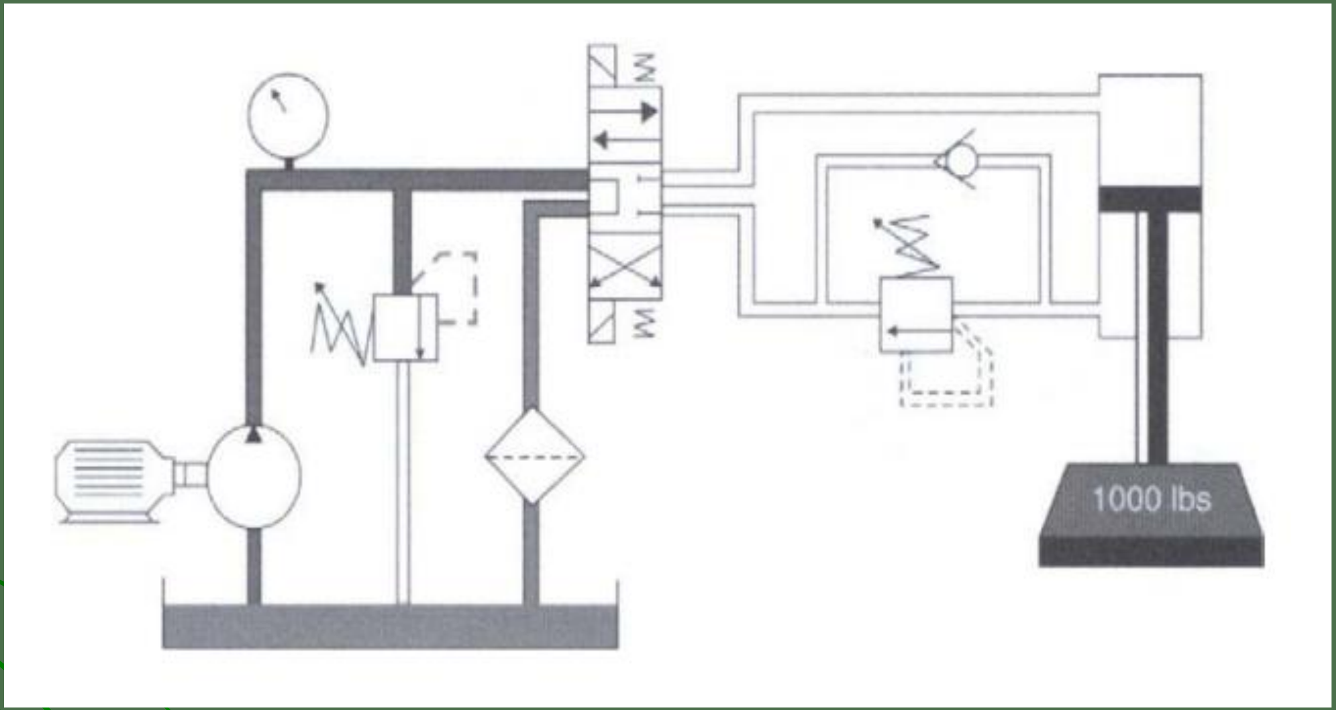


Fig 4.30b. **Symbol**



Application of counter balance valve



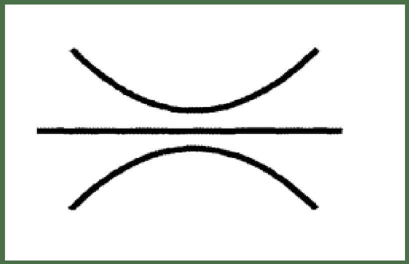
Vertical presses, loaders, lift trucks and other machine tool that must position or suspended load.

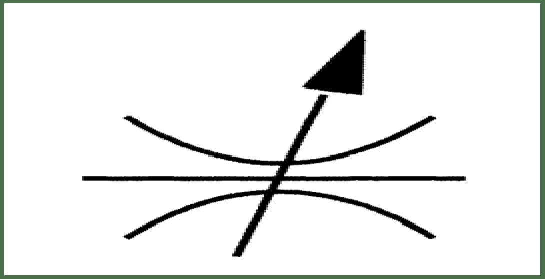
FLOW CONTROL VALVES

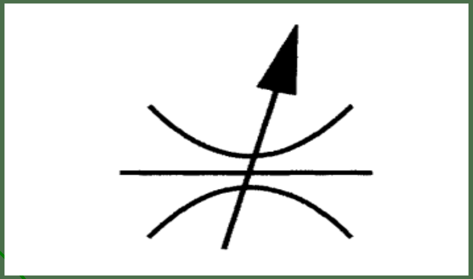
- *Classification of flow control valve*

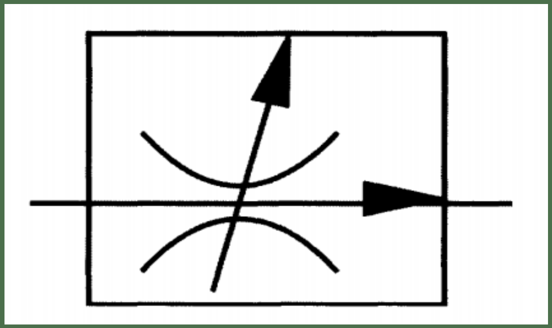
- Fixed flow control valve
- Adjustable flow control valve
- Throttling flow control valve
- Pressure compensated flow control valve

Symbols for flow control valve

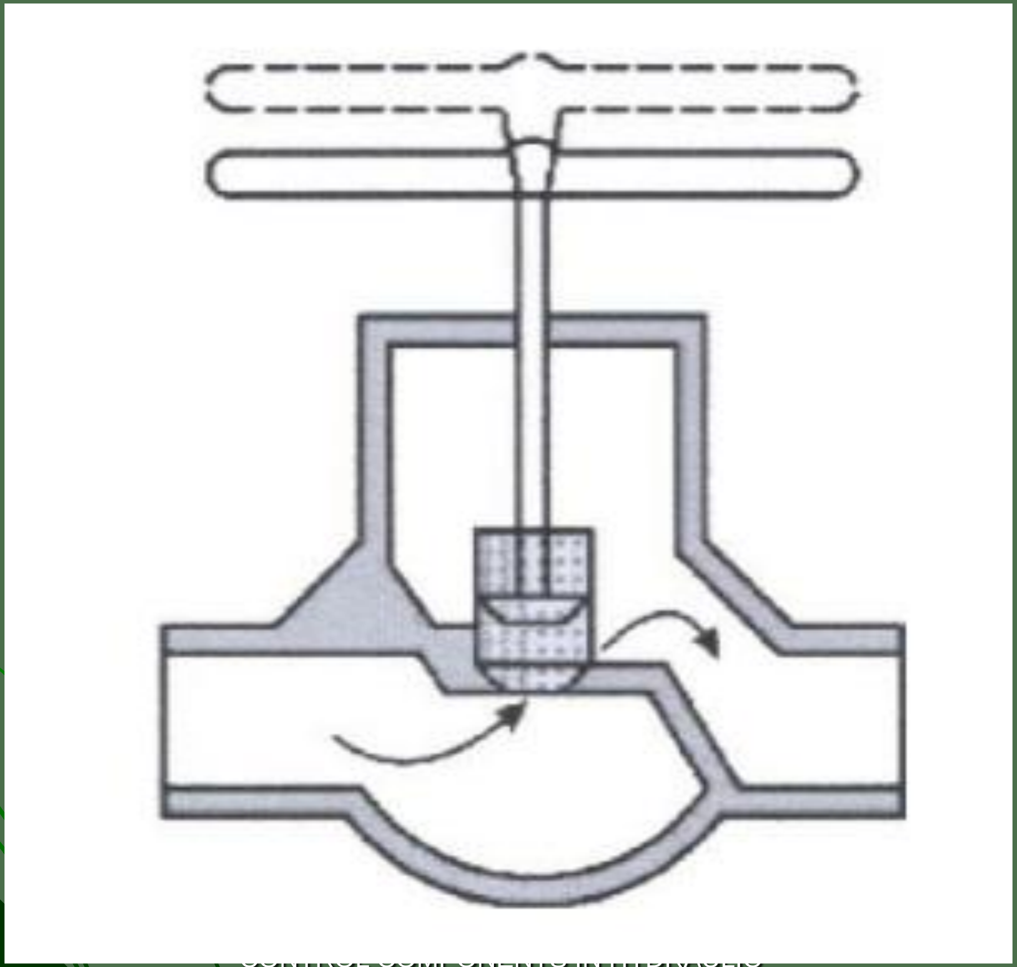




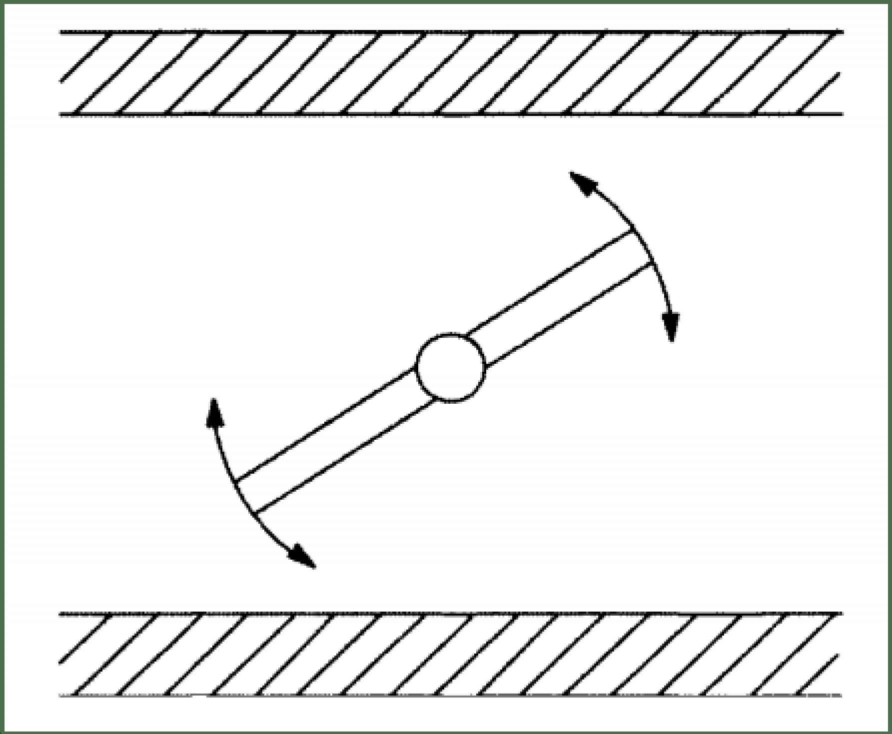




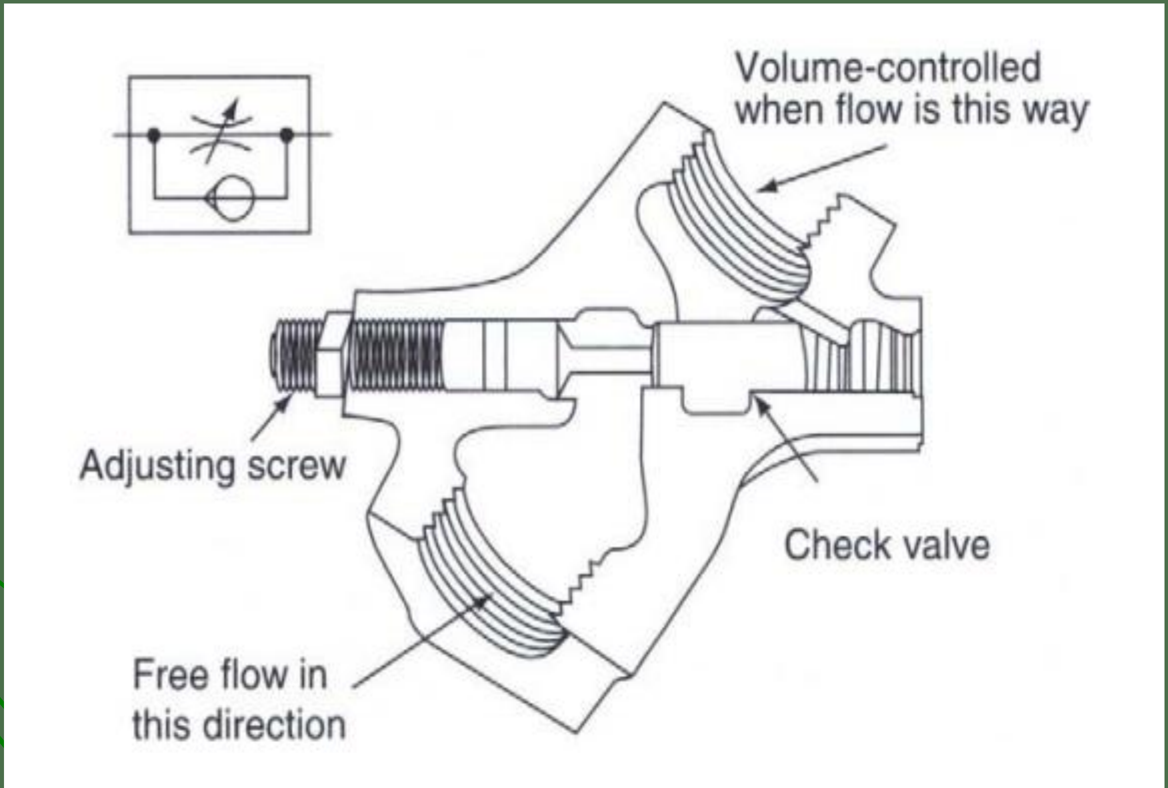
Globe valve



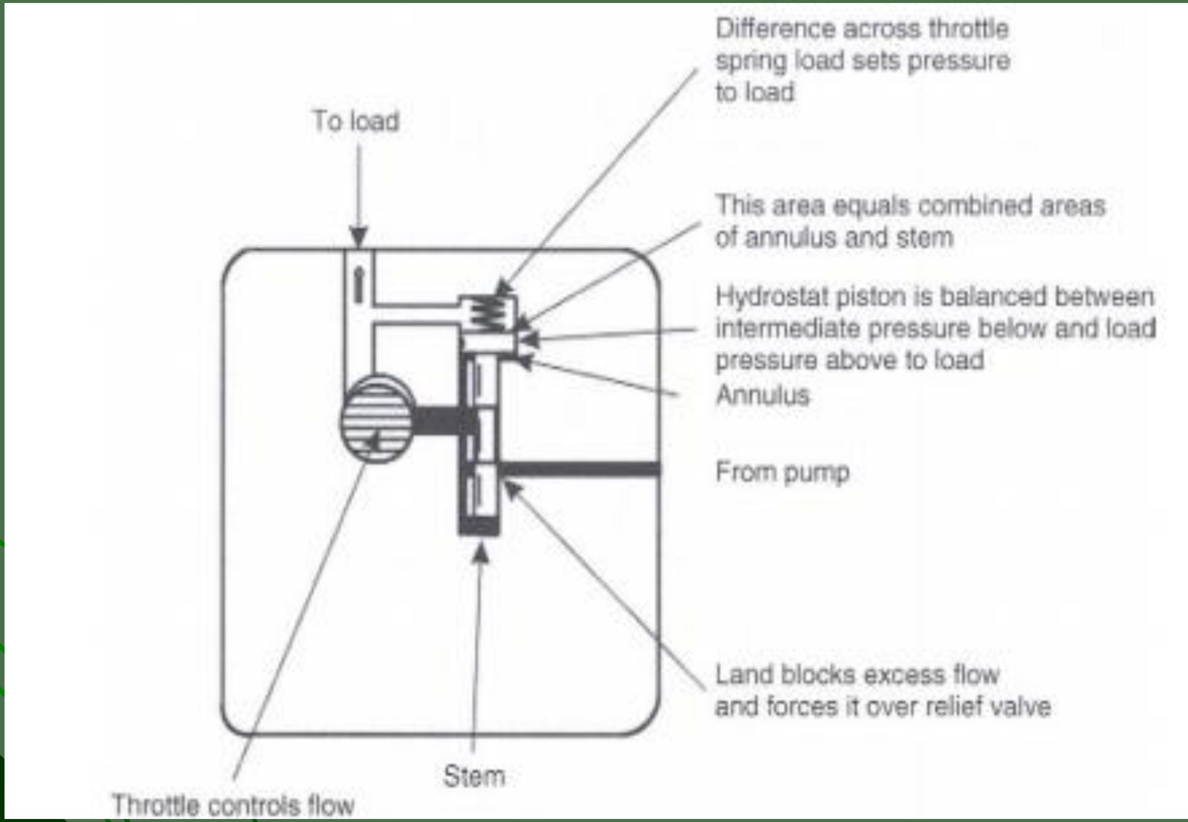
Butterfly valve



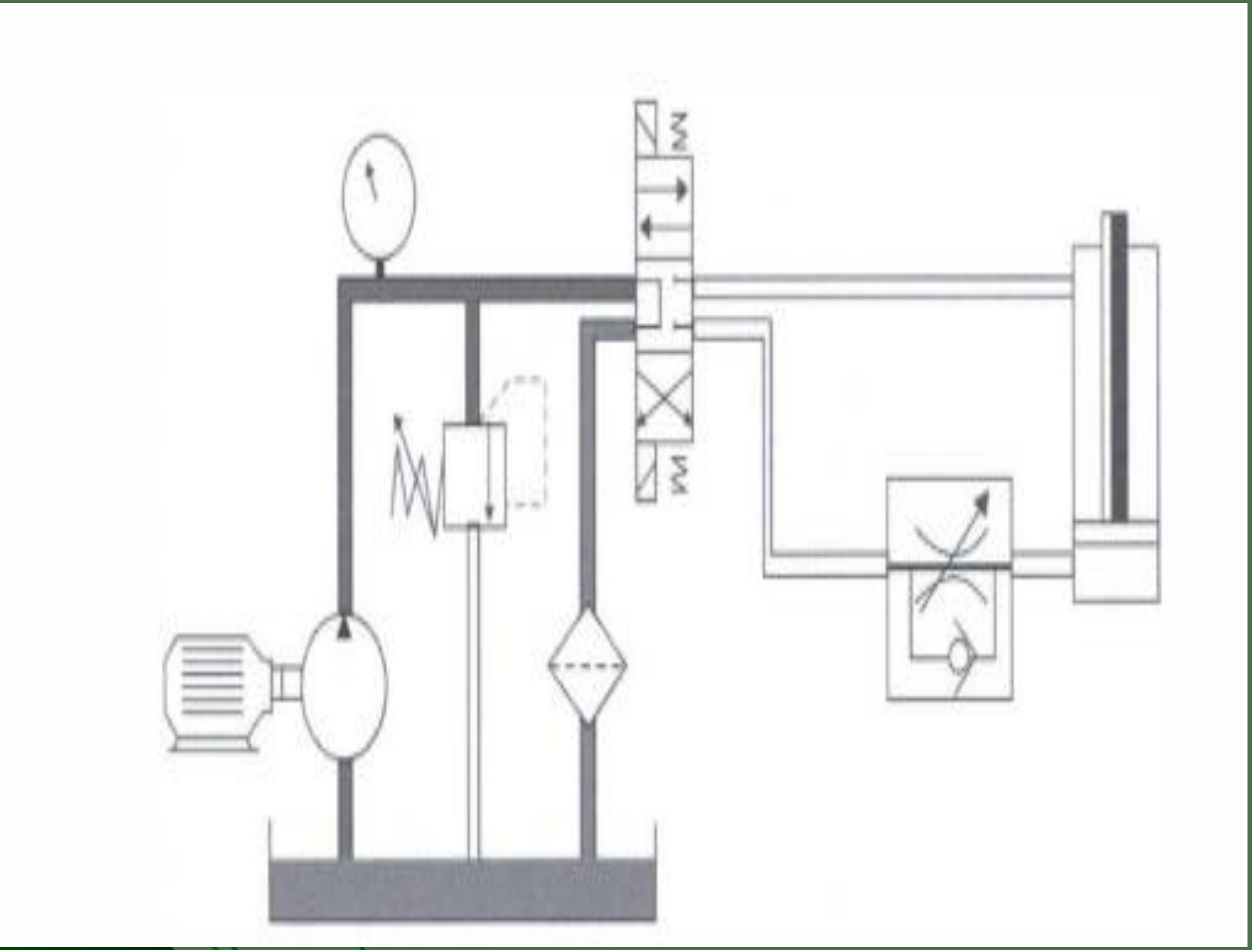
NON PRESSURE COMPANSATED FLOW CONTROL VALVE



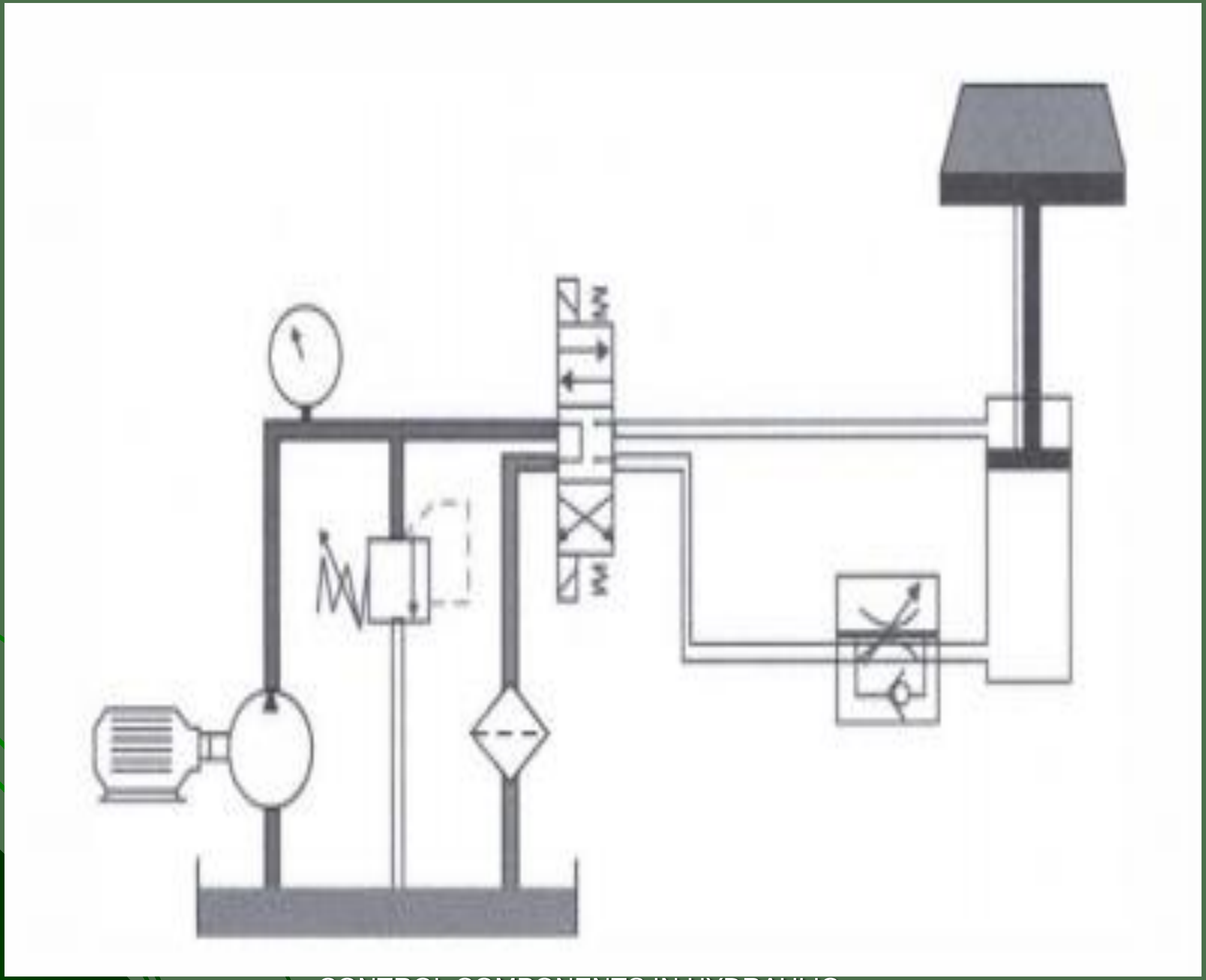
Pressure compensated flow control valve



Meter in operation



Meter out application



HYDARULICS AND PNEUMATICS

UNIT – 4

HYDRAULIC CIRCUIT DESIGN AND ANALYSIS

HYDRAULIC CIRCUIT DESIGN AND ANALYSIS

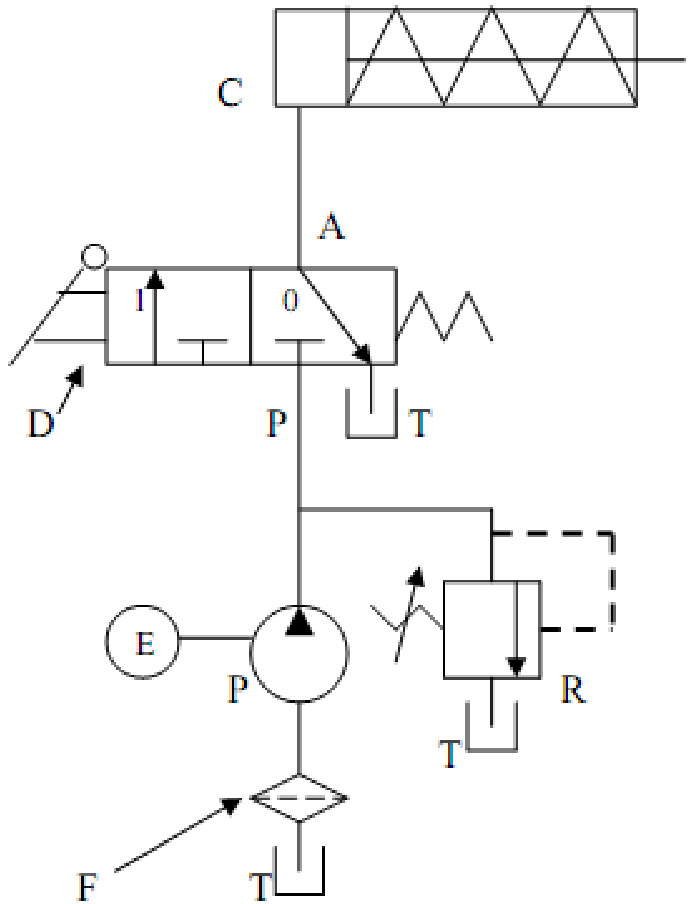
- **HYDARULIC CIRCUIT:-** Hydraulic circuit is a group of components such as pumps, actuators, control valves, and conductors arranged so that they will perform useful task.

HYDRAULIC CIRCUIT DESIGN AND ANALYSIS

- *IMPORTANT CONSIDERATIONS*

- Safety of operation
- Performance of desired function
- Efficiency of operation

CONTROL OF A SINGLE ACTING HYDRAULIC CYLINDER



C = Single acting cylinder

P = Pump

E = Electric Motor

T = Tank

F = Filter

R = Relief Valve

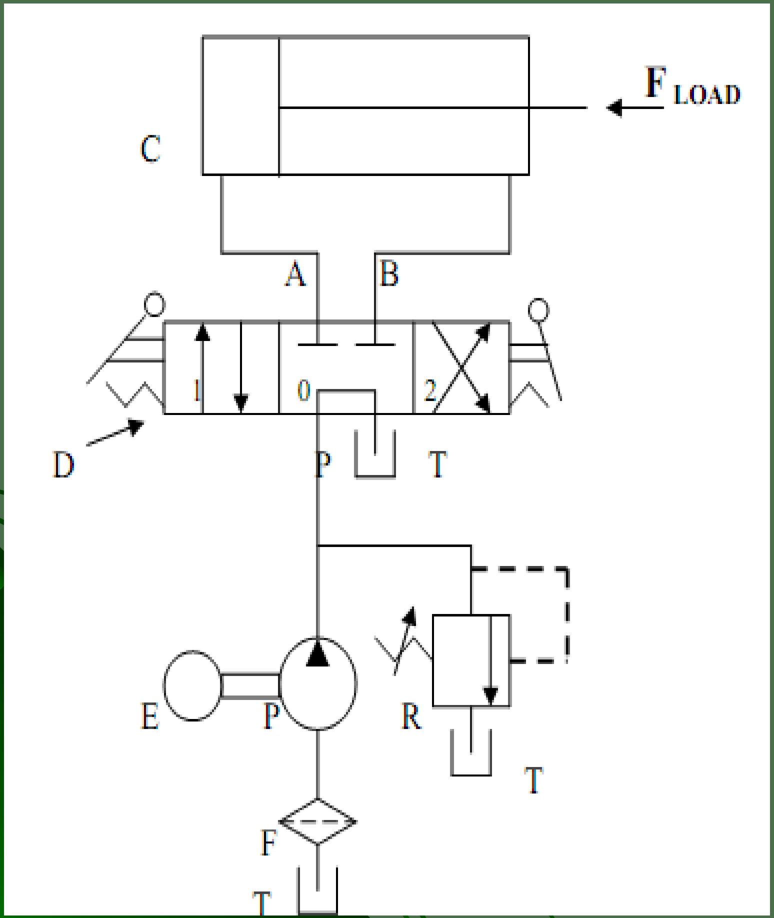
D =2-position, 3 way DCV Manually operated and spring return

Analysis of force and velocity in single acting cylinder

Force during extension stroke is , $F_{ext} = p \cdot A_P$

Velocity during extension stroke is , $v_{P\,ext} = Q_P / A_P$

CONTROL OF A DOUBLE ACTING HYDRAULIC CYLINDER



C = Double acting cylinder

P = Pump

E = Electric Motor

T = Tank

F = Filter

R = Relief Valve

D =3-position, 4 way ,Tandem center, Manually operated and Spring Centered DCV

Analysis of force and velocity of double acting cylinder

<u>Extending stroke</u> :

Force, $F_{ext} = p \cdot A_P$ -------- 1

Velocity, $v_{ext} = Q_p / A_P$ -----2

<u>Retraction Stroke</u> :

Force, $F_{ret} = p \cdot (A_P - A_r)$ --- 3

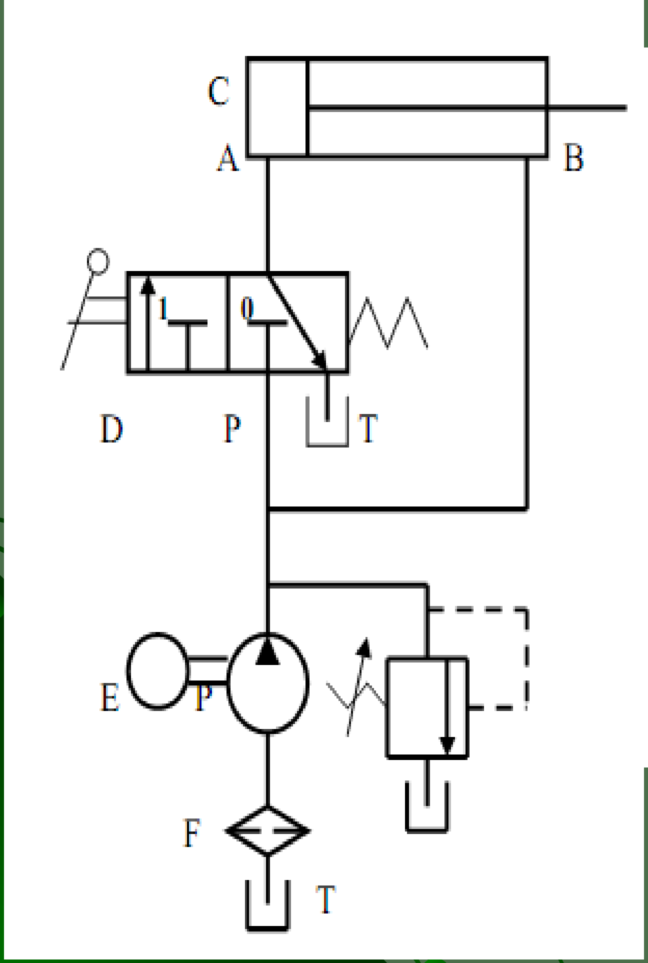
Velocity, $v_{ret} = Q_p / (A_P - A_r)$ --- 4

$$Power\,(kW) = v_p\,(m/s) \cdot F\,(kN) = Q\,(m^3/s) \cdot p\,(kPa)$$

DOUBLE ACTING CYLINDER

- A pump supplies oil at 0.0016 cubic meter per second to a 40 mm diameter double acting hydraulic cylinder. If the load is 5000 N (extending and retracting) and rod diameter is 20 mm find the
- Hydraulic pressure during the extending stroke
- Piston velocity during the extending stroke
- Cylinder KW power during the extending stroke
- Hydraulic pressure during retracting stroke
- Piston velocity during the retraction stroke
- Cylinder KW power during the retraction stroke

REGENERATIVE CIRCUIT



C = Double acting cylinder

P = Pump

E = Electric Motor

T = Tank

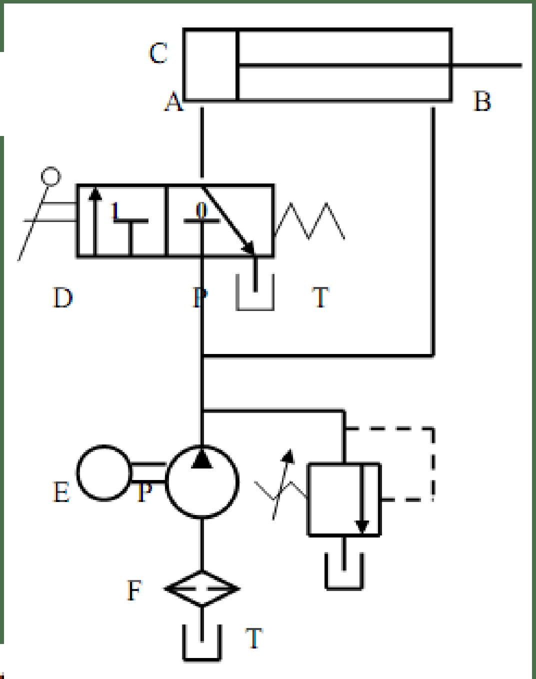
F = Filter

R = Relief Valve

D =2-position, 3 way , Manually operated and Spring return DCV

REGENERATIVE CIRCUIT ANALYSIS

Cylinder Extending Speed



$$Q_T = Q_P + Q_R$$

Or $$Q_P = Q_T - Q_R \quad \text{---(1)}$$

$$Q_P = A_p V_{pext} - (A_p - A_r) V_{pext}$$

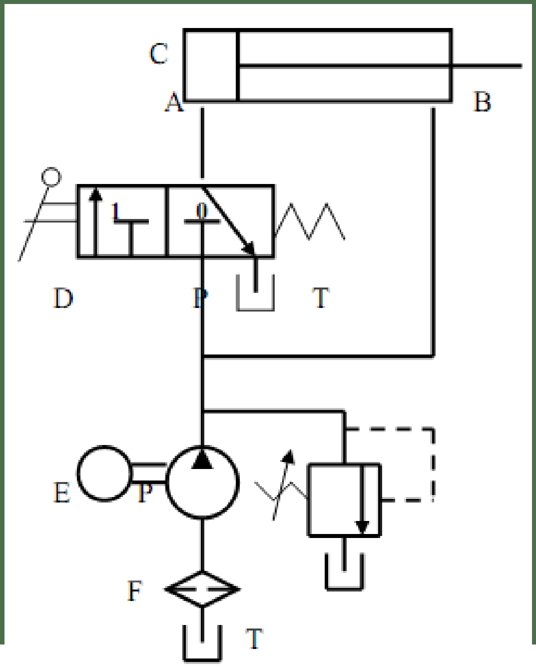
Therefore, $$Q_P = A_r V_{pext}$$

Hence the extending speed of the piston, $$V_{pext} = \frac{Q_p}{A_r} \quad \text{--- (2)}$$

REGENERATIVE CIRCUIT ANALYSIS

Ratio of Extending and Retracting Speeds

$$V_{pret} = \frac{Q_p}{A_p - A_r} \qquad ---(3)$$



Dividing eq(1) with (4) we have $$\frac{Vp_{ext}}{Vp_{ret}} = \frac{Qp / A_r}{Qp / (Ap - A_r)} = \frac{A_p - A_r}{A_r}$$

Simplifying we obtain the ratio of extension speed and retracting speed

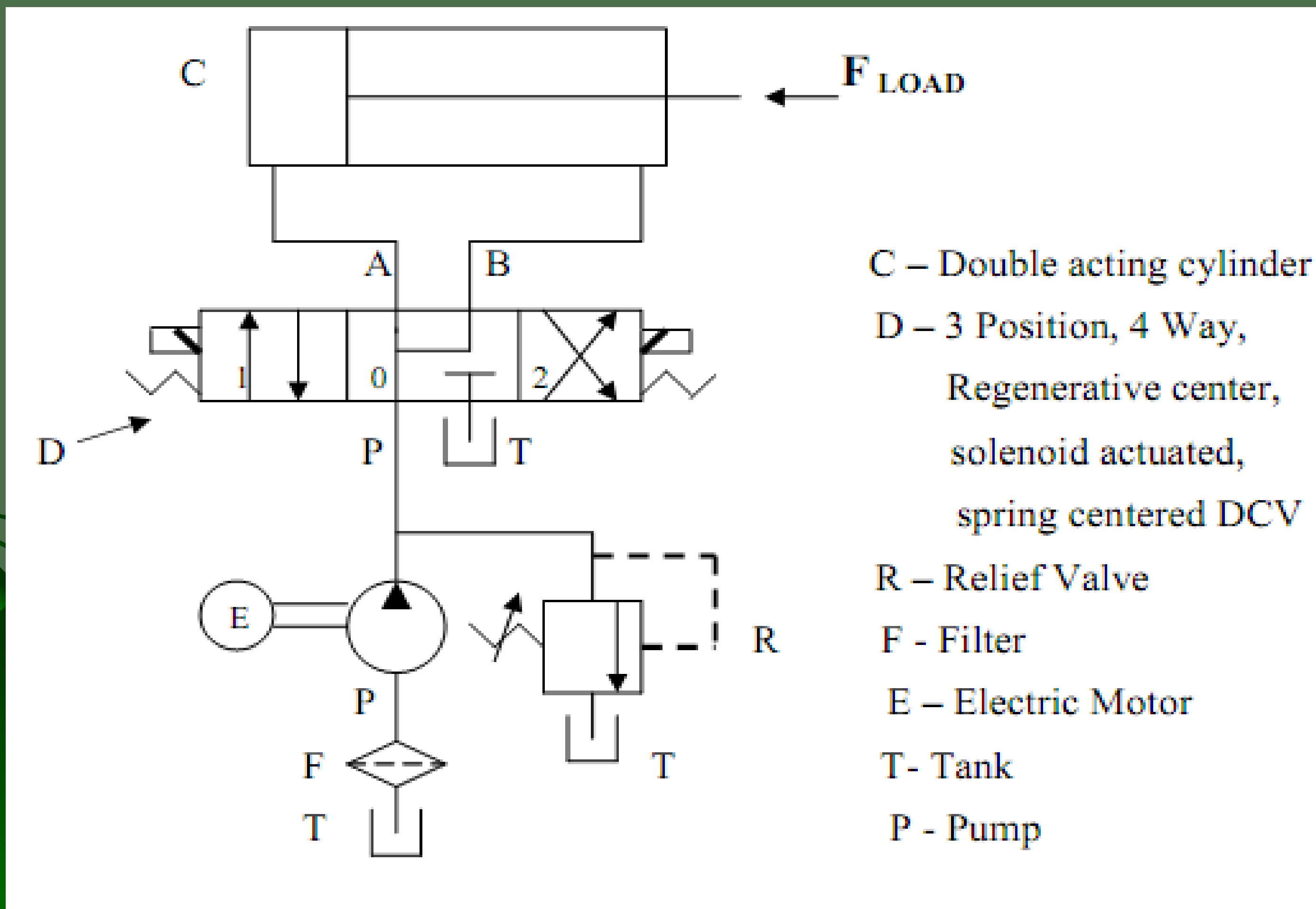
REGENERATIVE CIRCUIT ANALYSIS

$$\frac{Vp_{ext}}{Vp_{ret}} = \frac{Ap}{A_r} - 1 \qquad --(4)$$

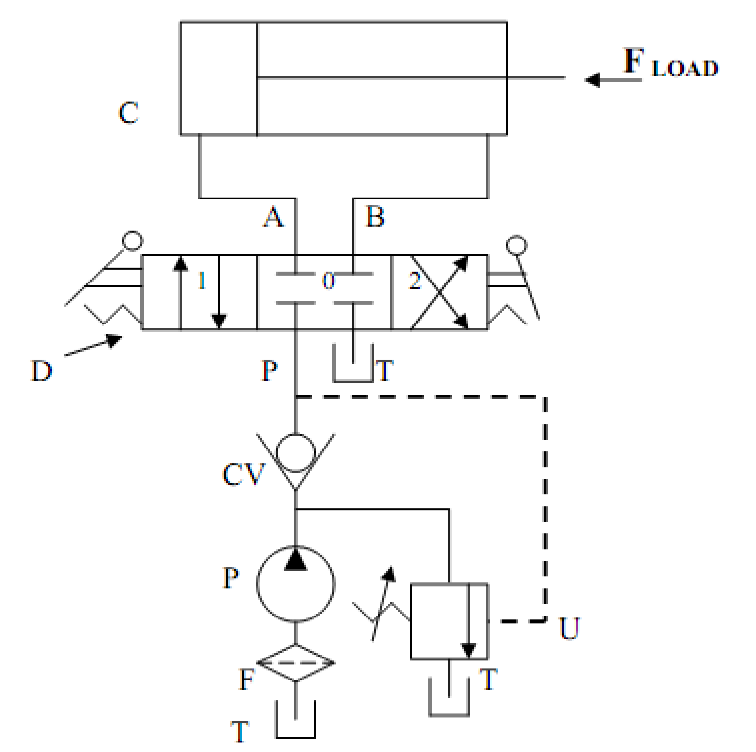
Load-Carrying Capacity during Extension :

$$F_{load} = PA_r$$

Application of Regenerative Circuit in Drilling



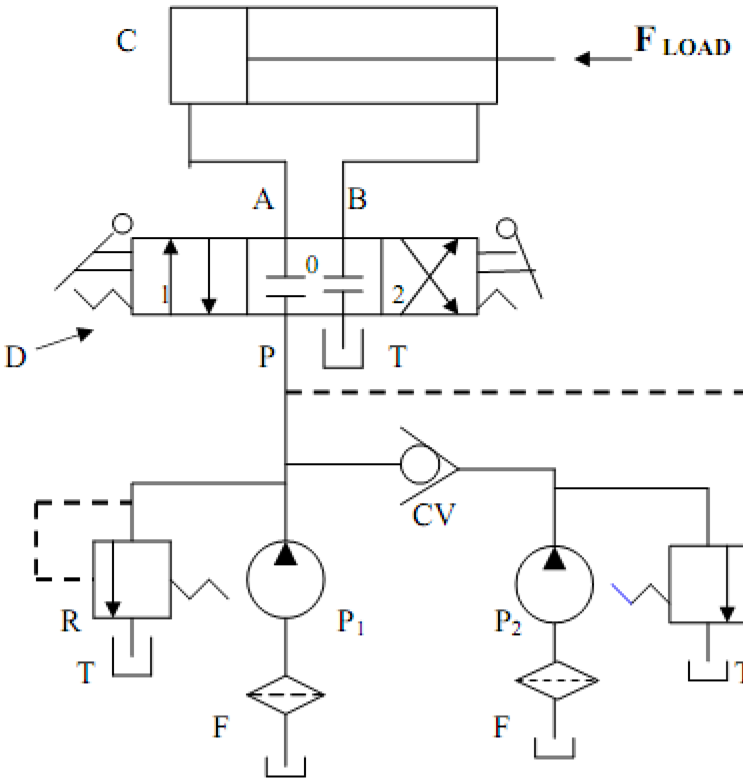
PUMP UNLOADING CIRCUIT



C = Double acting cylinder P = Pump T = Tank F = Filter U = unloading Valve

D =3-position, 4 way ,closed center, Manually operated and Spring Centered DCV

DOUBLE PUMP HYDRAULIC SYSTEM



P_1 -- Low discharge, High pressure pump

P_2 -- High discharge, Low pressure pump

R -- Relief valve

U – Unloading valve

T - Tank

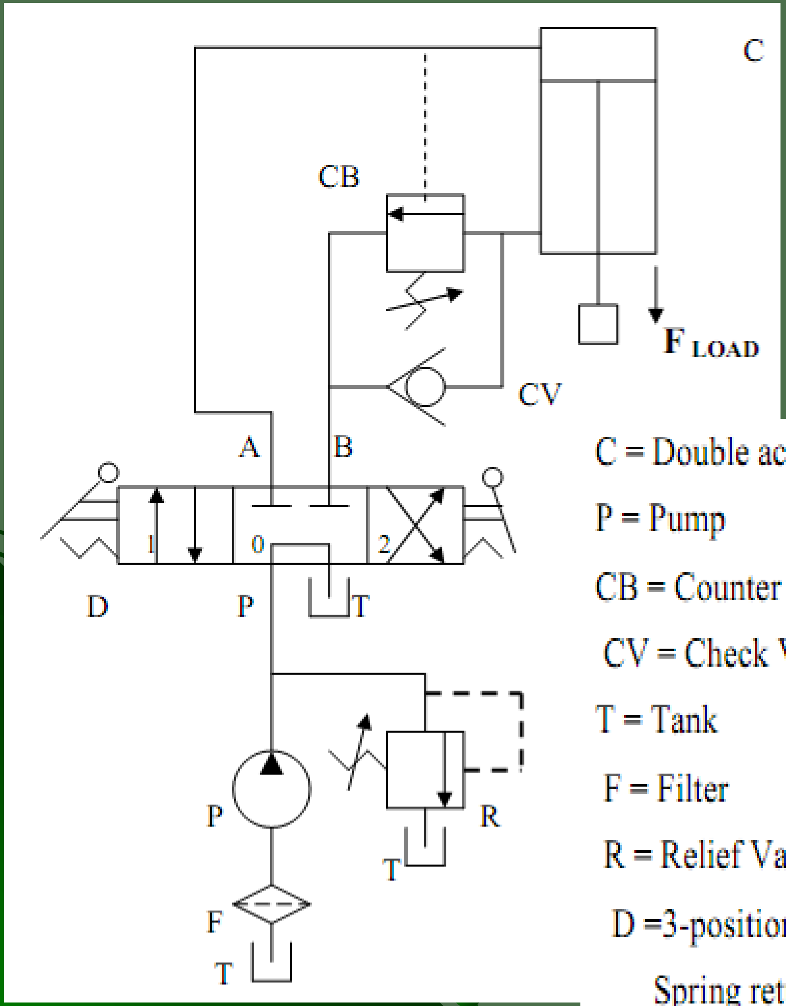
CV – Check valve

D – 3 Position, 4 Way, closed center, manual actuated DCV

C- Double acting cylinder

F - Filter

COUNTER BALANCE VALVE APPLICATION



C = Double acting cylinder mounted vertically

P = Pump

CB = Counter Balance Valve

CV = Check Valve

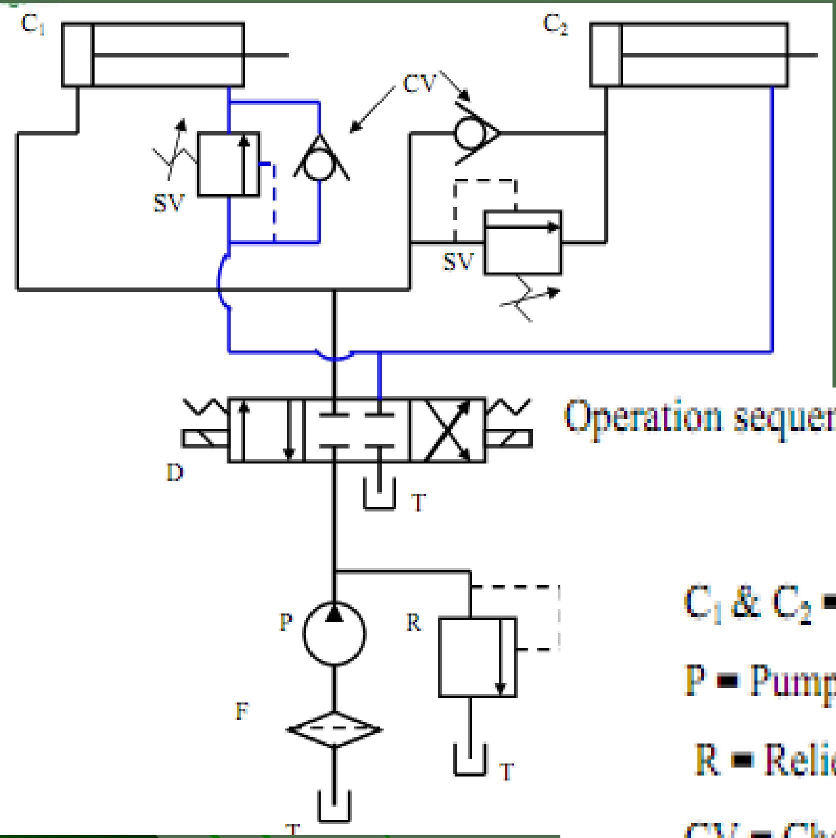
T = Tank

F = Filter

R = Relief Valve

D =3-position, 4 way , Tandem center, Manually operated and Spring return DCV

HYDRAULIC CYLINDER SEQUENCING CIRCUIT



Operation sequence is : $C_1+ C_2+ C_2- C_1-$

+ is Extension of piston

- is Retraction of piston

C_1 & C_2 = Double acting cylinder

P = Pump ; SV = Sequence Valve ;

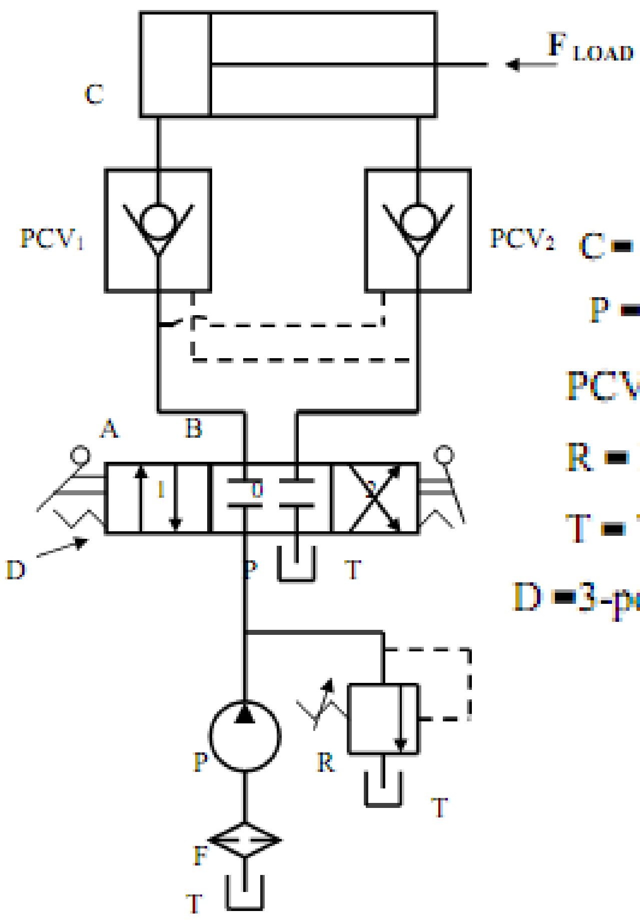
R = Relief Valve

CV = Check Valve ;

T = Tank ; F = Filter

D = 3-position, 4 way , Tandem center, Solenoid operated and Spring return DCV

LOCKED CYLINDER USING PILOT CHECK VALVE



C = Double acting cylinder

P = Pump

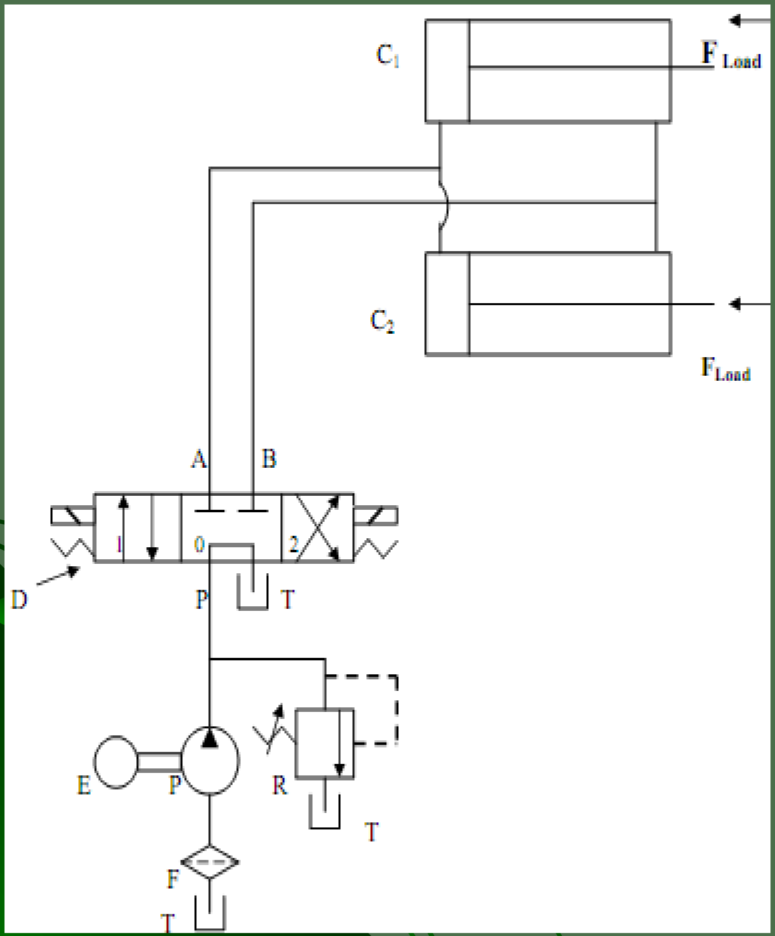
PCV_1 & PCV_2 = Pilot Check Valve

R = Relief Valve

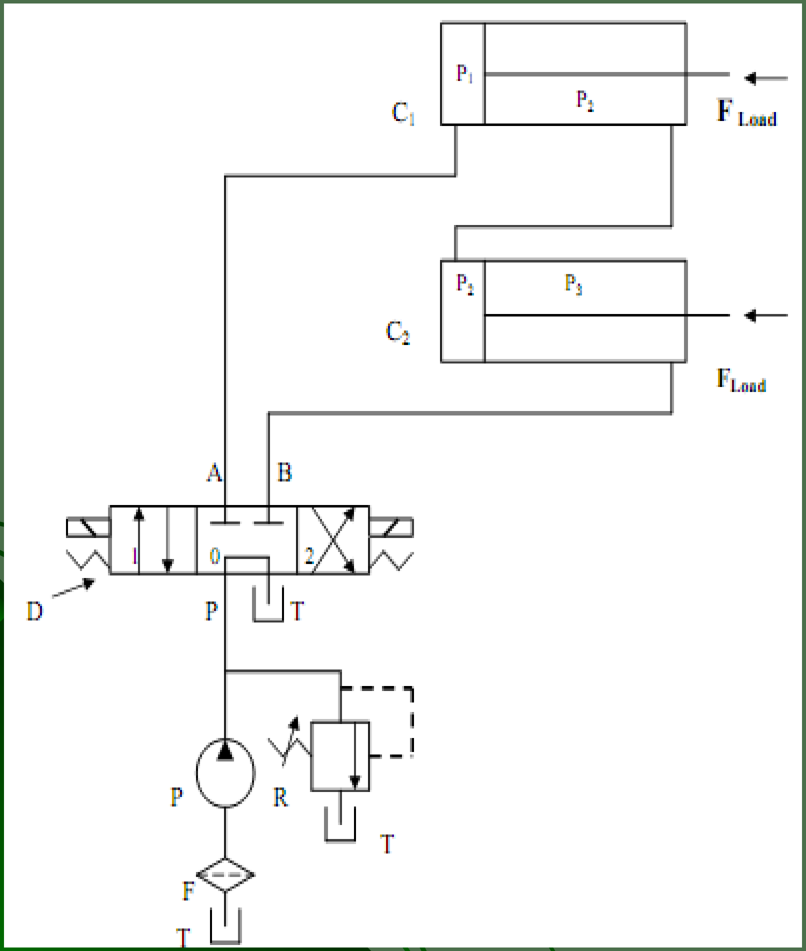
T = Tank ; F = Filter

D =3-position, 4 way , closed center, manually operated DCV

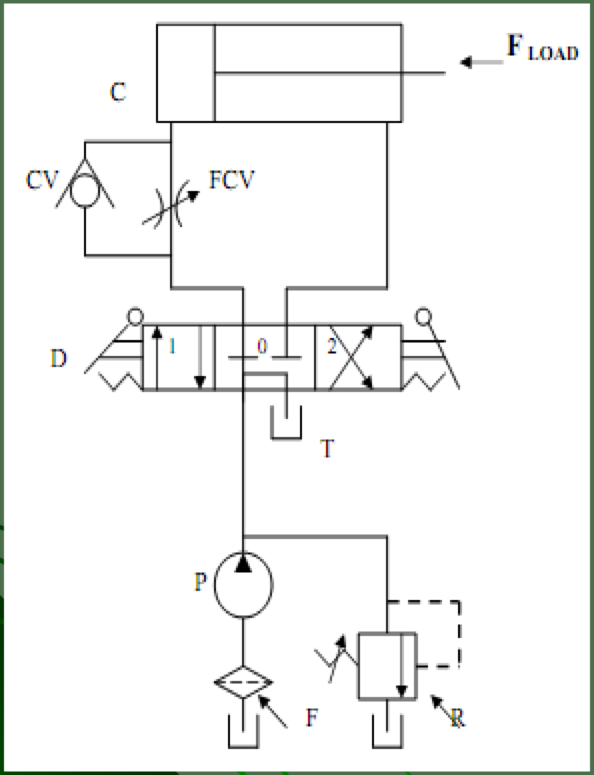
CYLINDER HOOKED IN PARALLEL FOR SYNCHRONIZING (WILL NOT OPERATE)



Cylinder hooked in series for synchronizing (will operate)



METER IN CIRCUIT

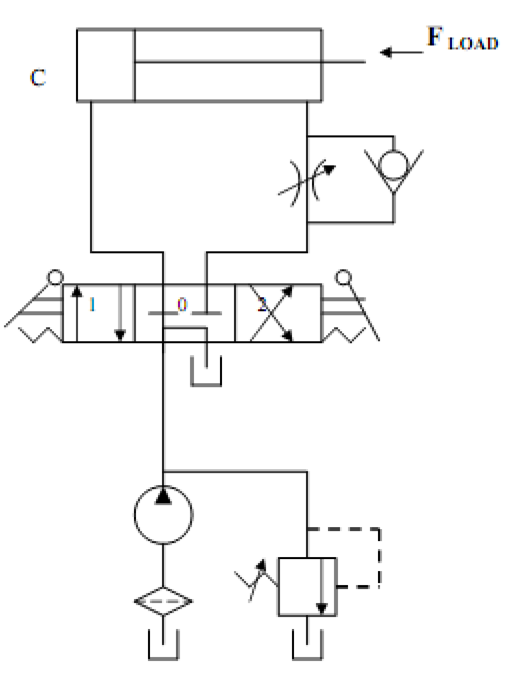


C = Double acting cylinder ; P = Pump ; T = Tank ; F = Filter

R = Relief Valve; CV = Check Valve ; FCV = Flow control Valve

D =3-position, 4 way ,Tandem center, Manually operated ,Spring Centered DCV

METR OUT CIRCUIT

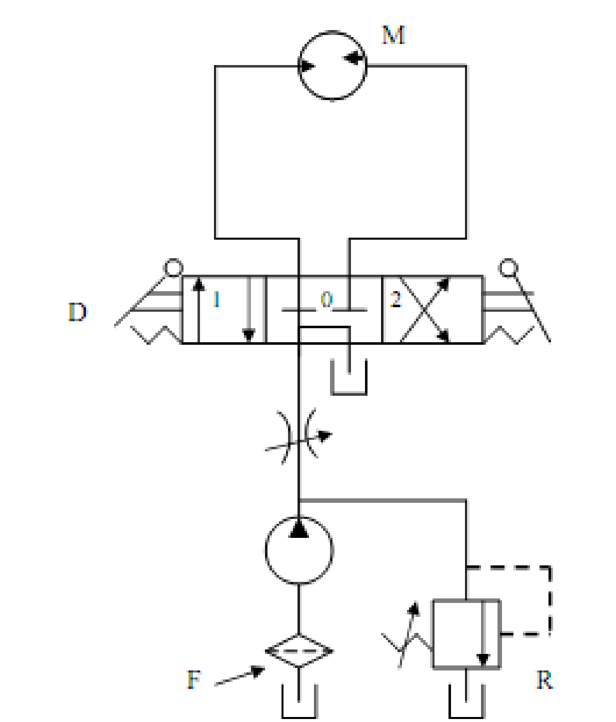


C = Double acting cylinder; P = Pump ; T = Tank; F = Filter

R = Relief Valve; CV = Check Valve ; FCV = Flow control Valve

D =3-position, 4 way ,Tandem center, Manually operated and Spring Centered DCV

SPEED CONTROL OF HYDRAULIC MOTOR USING FLOW CONTROL VALVE

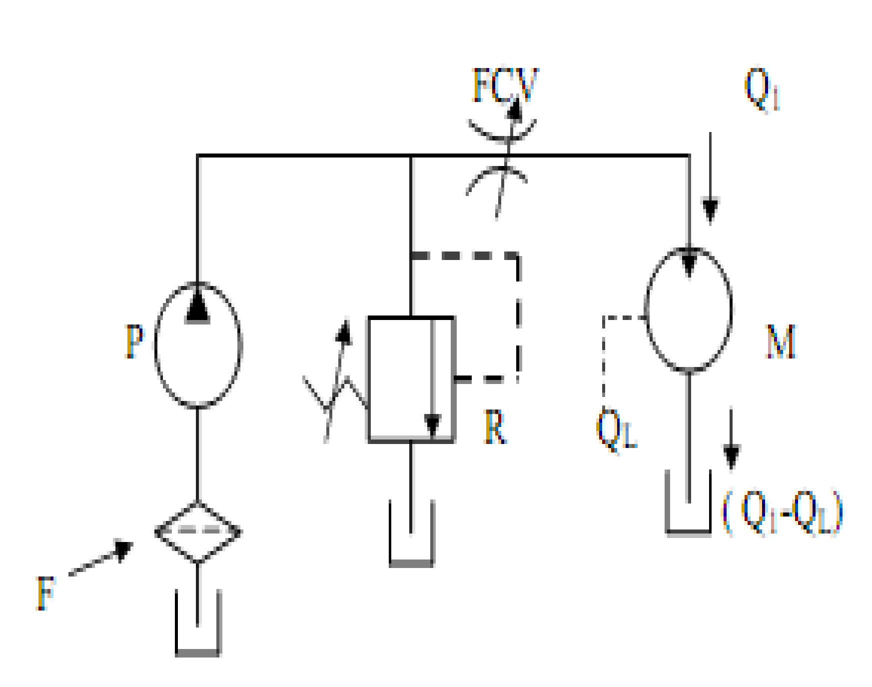


M = Bi-directional Hydraulic motor ; P = Pump ; T = Tank; F = Filter

R = Relief Valve; FCV = Flow control Valve

D =3-position, 4 way ,Tandem center, Manually operated and Spring Centered DCV

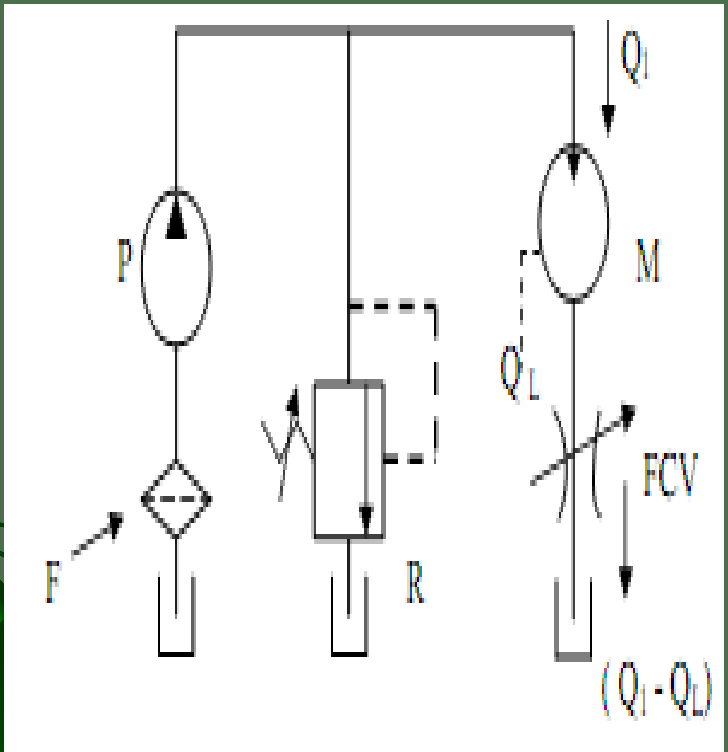
METER IN SPEED CONTROL OF HYDRAULIC MOTOR



M = Uni-directional Hydraulic Motor ; P = Pump ; T = Tank; F = Filter

R = Relief Valve; FCV = Flow control Valve

METER OUT SPEED CONTROL OF HYDRAULIC MOTOR



M = Uni-directional Hydraulic Motor ; P = Pump ; T = Tank; F = Filter

R = Relief Valve; FCV = Flow control Valve

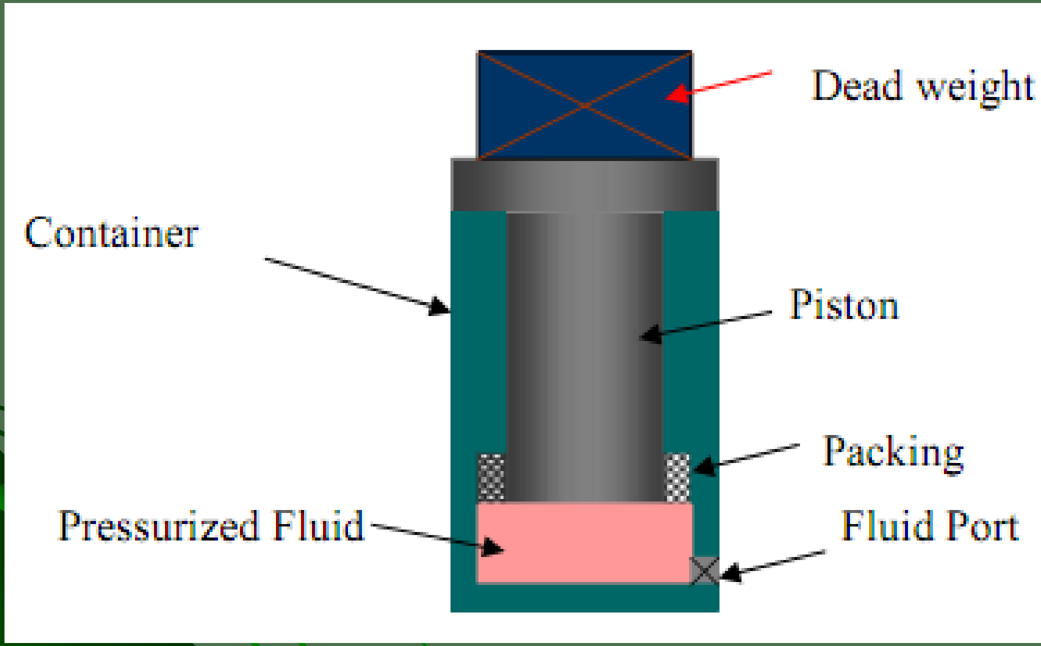
ACCUMULATORS AND ACCUMULATOR CIRCUITES

- An accumulator is a device that stores potential energy by means of either gravity, mechanical spring, or compressed gases.
- The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work as required by the system.

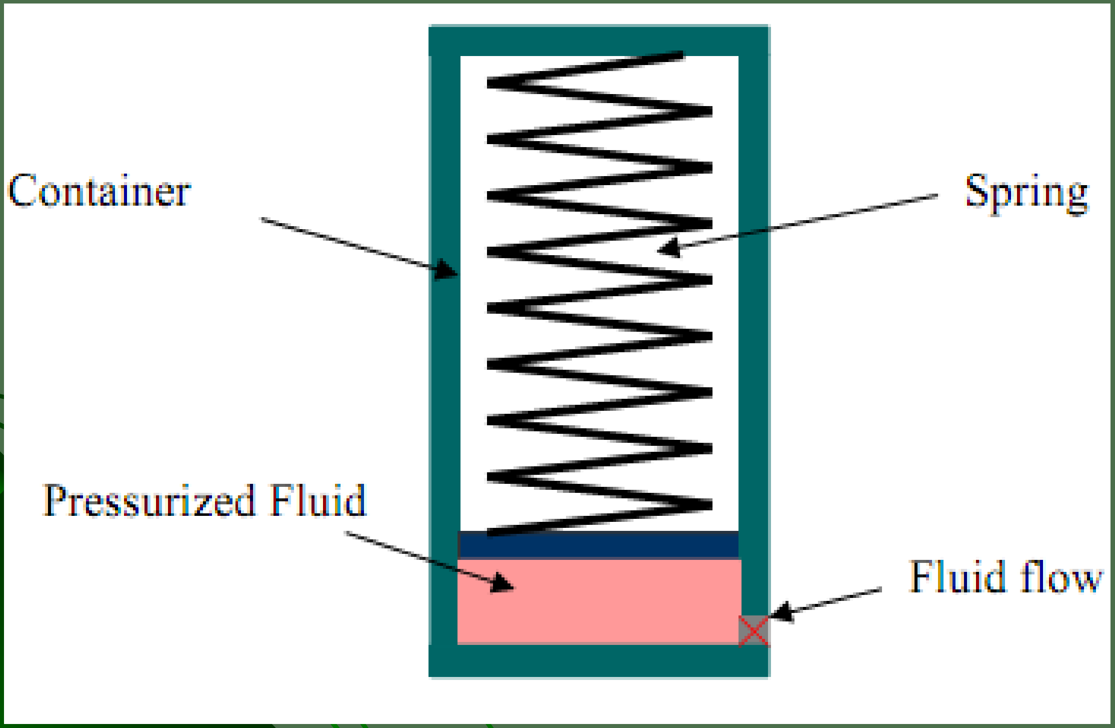
TYPES OF ACCUMULATORS

- WEIGHT LOADED OR GRAVITY TYPE ACCUMULATOR
- SPRING – LOADED TYPE ACCUMULATOR
- GAS – LOADED TYPE ACCUMULATOR

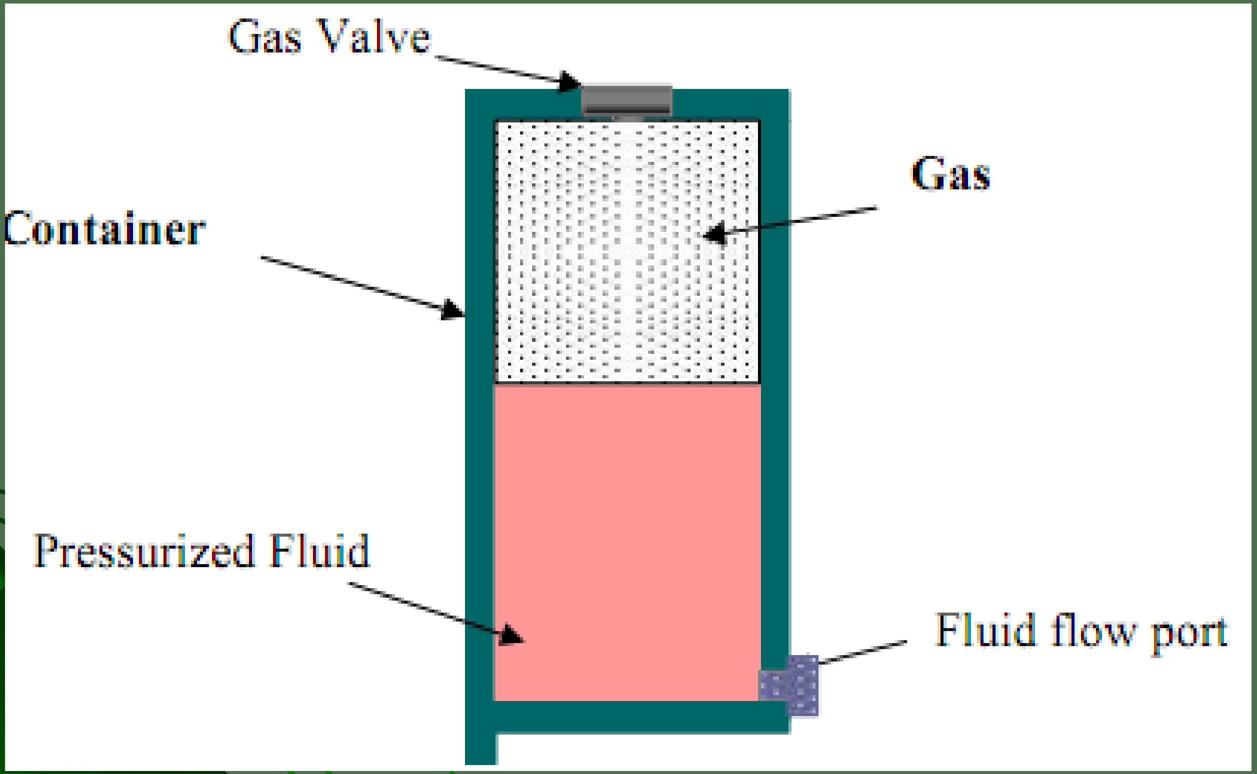
WEIGHT – LOADED, OR GRAVITY TYPE ACCUMULATOR



SPRING – LOADED TYPE ACCUMULATOR



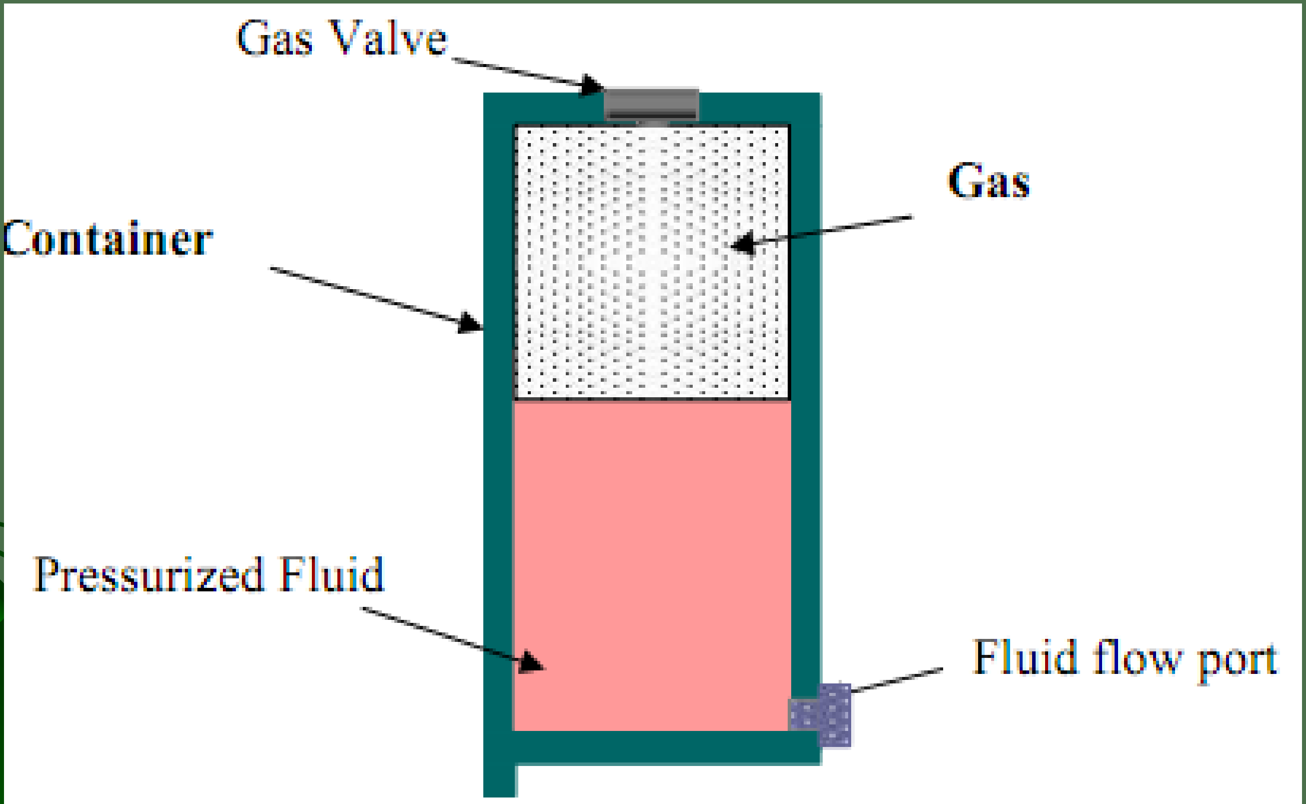
GAS – LOADED TYPE ACCUMULATOR



TYPES OF GAS LOADED ACCUMULATOR

- NON – SEPARATOR TYPE
- SEPARATOR TYPE

NON – SEPARATOR TYPE

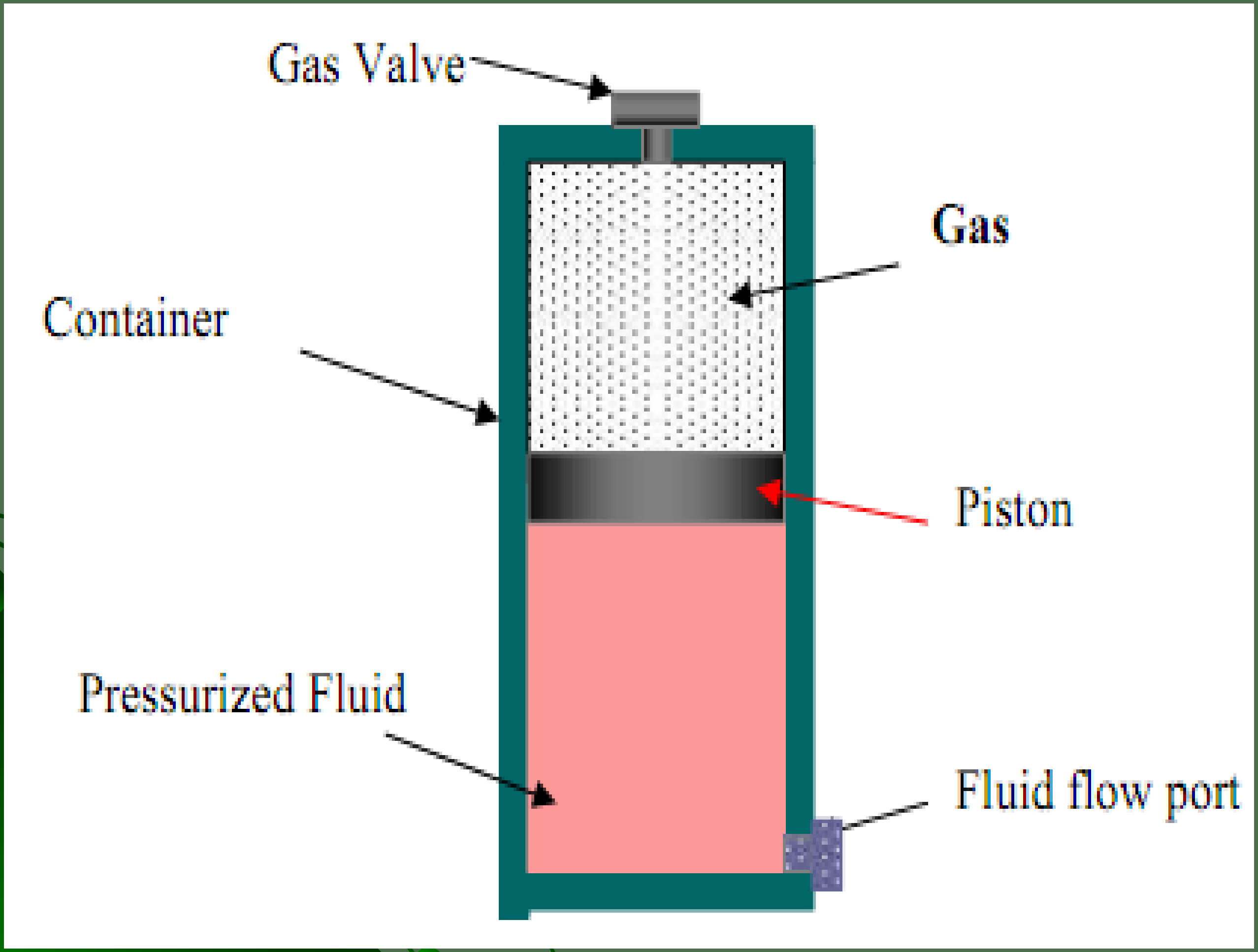


SEPARATOR TYPE

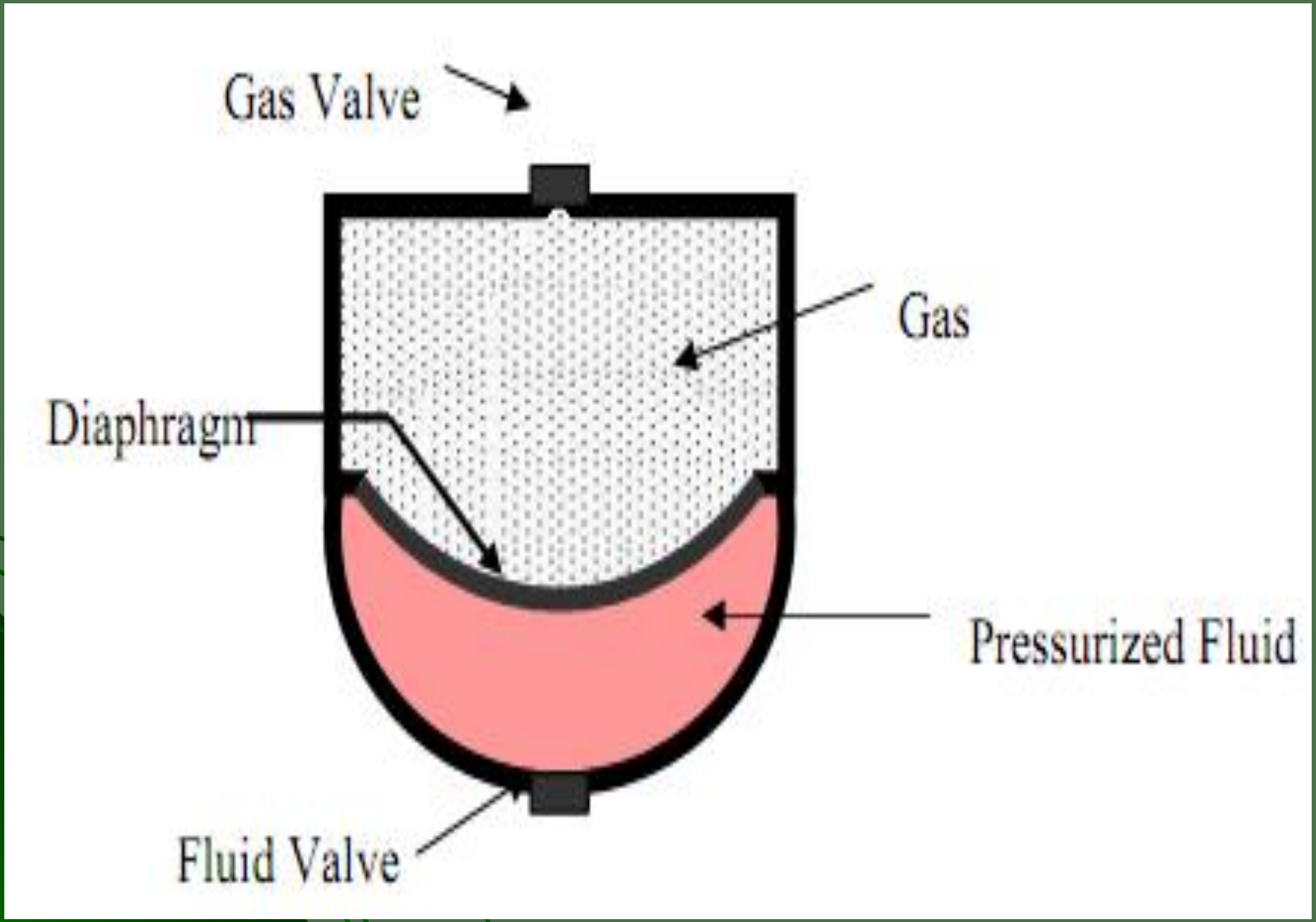
- Separator type accumulator is intern classified into.

- The piston type
- Diaphragm type
- The bladder type

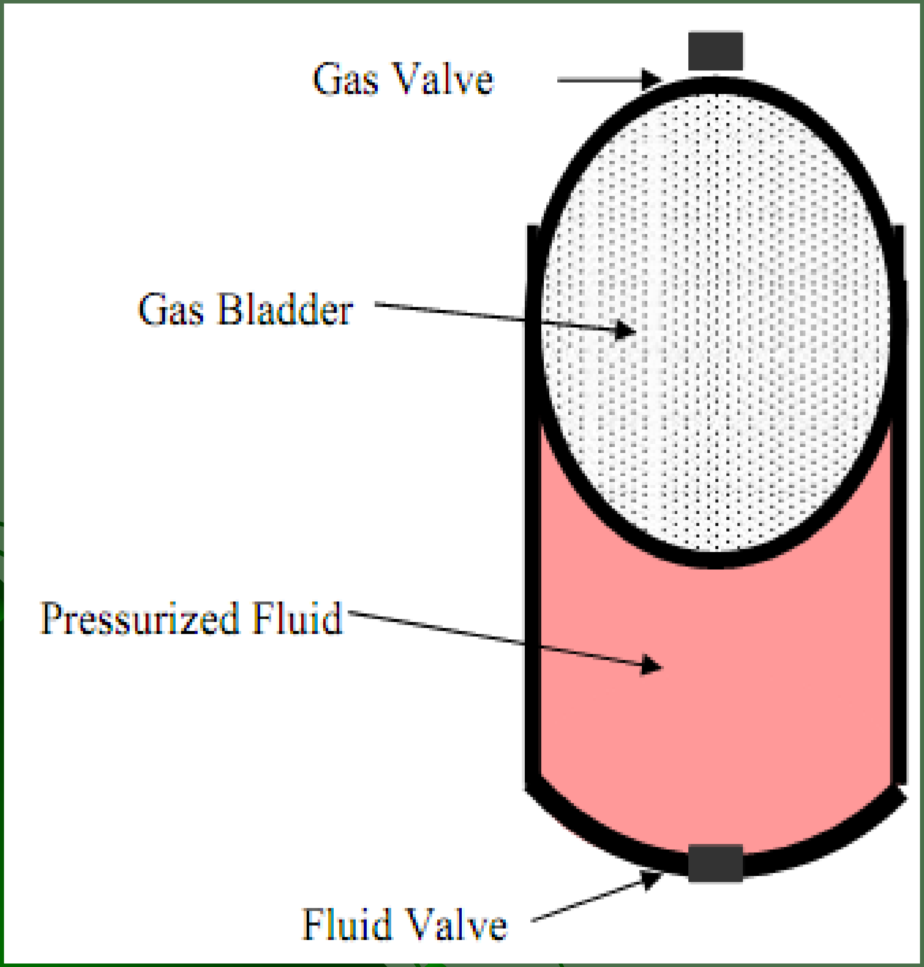
Piston type separator gas accumulator



Diaphragm type separator gas accumulator



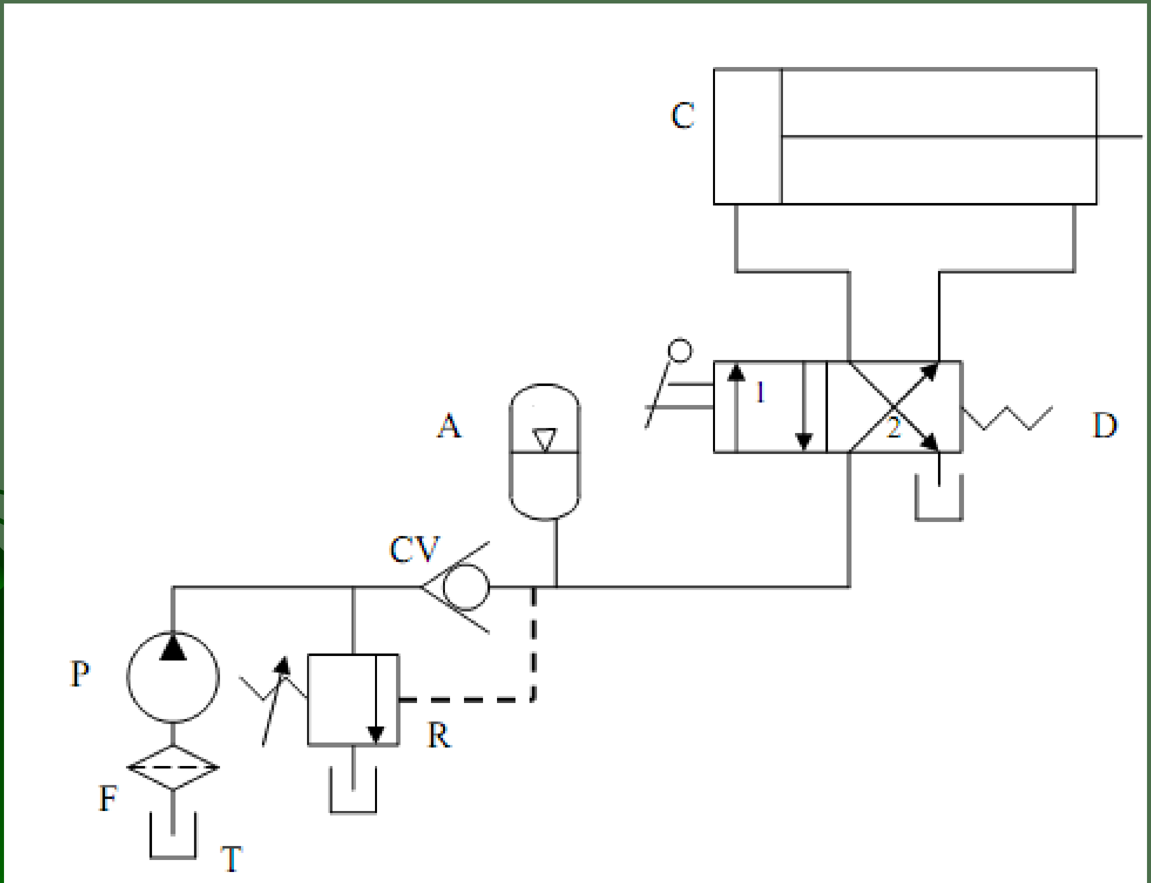
Bladder type gas loaded accumulator



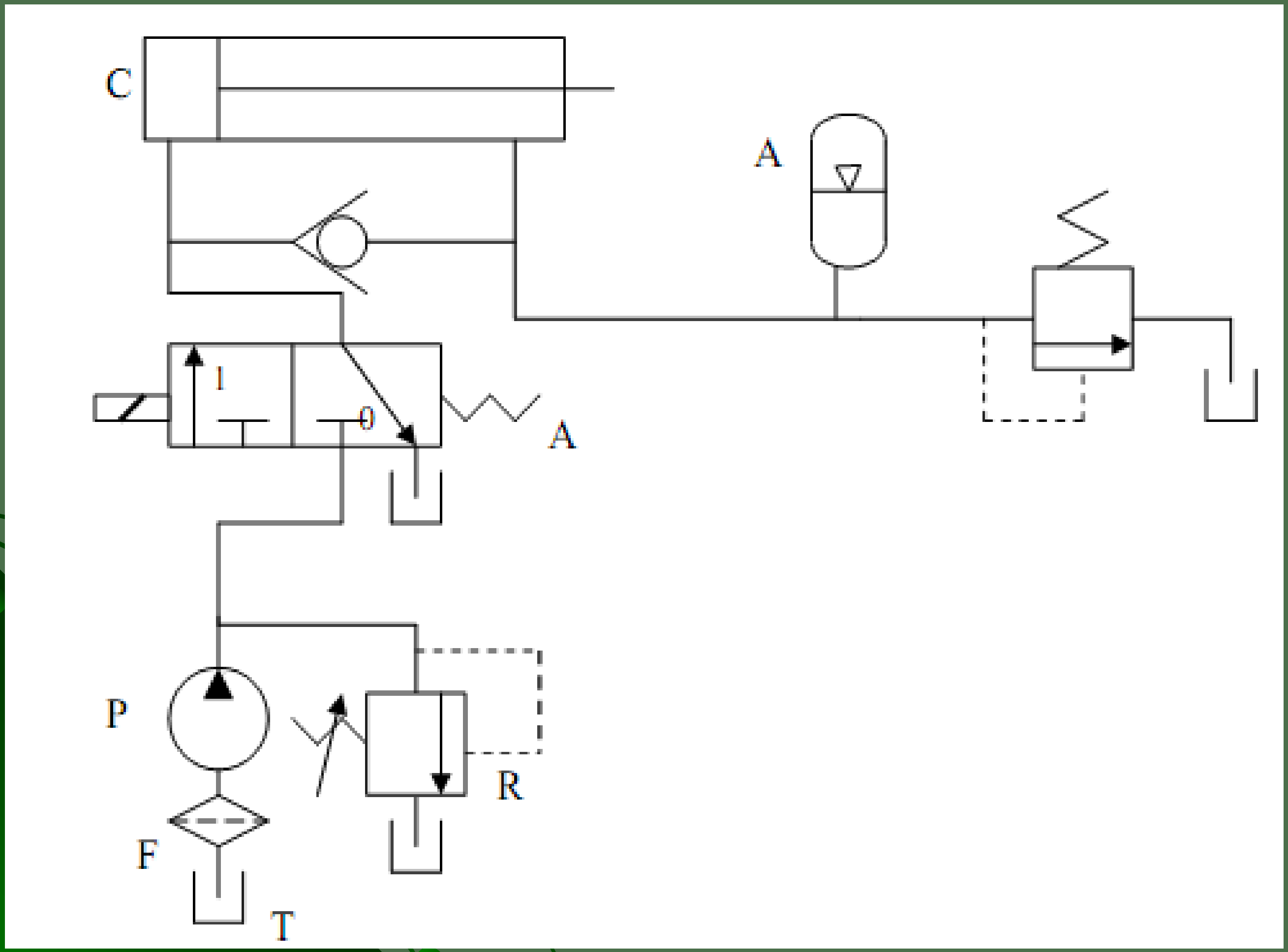
ACCUMULATOR APPLICATIONS

- ACCMULATOR AS A AUXILIARY POWER SOURCE
- ACCUMULATOR AS AN EMERGENCY POWER SOURCE
- ACCUMULATOR AS A SHOCK ABSORBER
- ACCUMULATOR AS A LEAKAGE COMPANSATOR

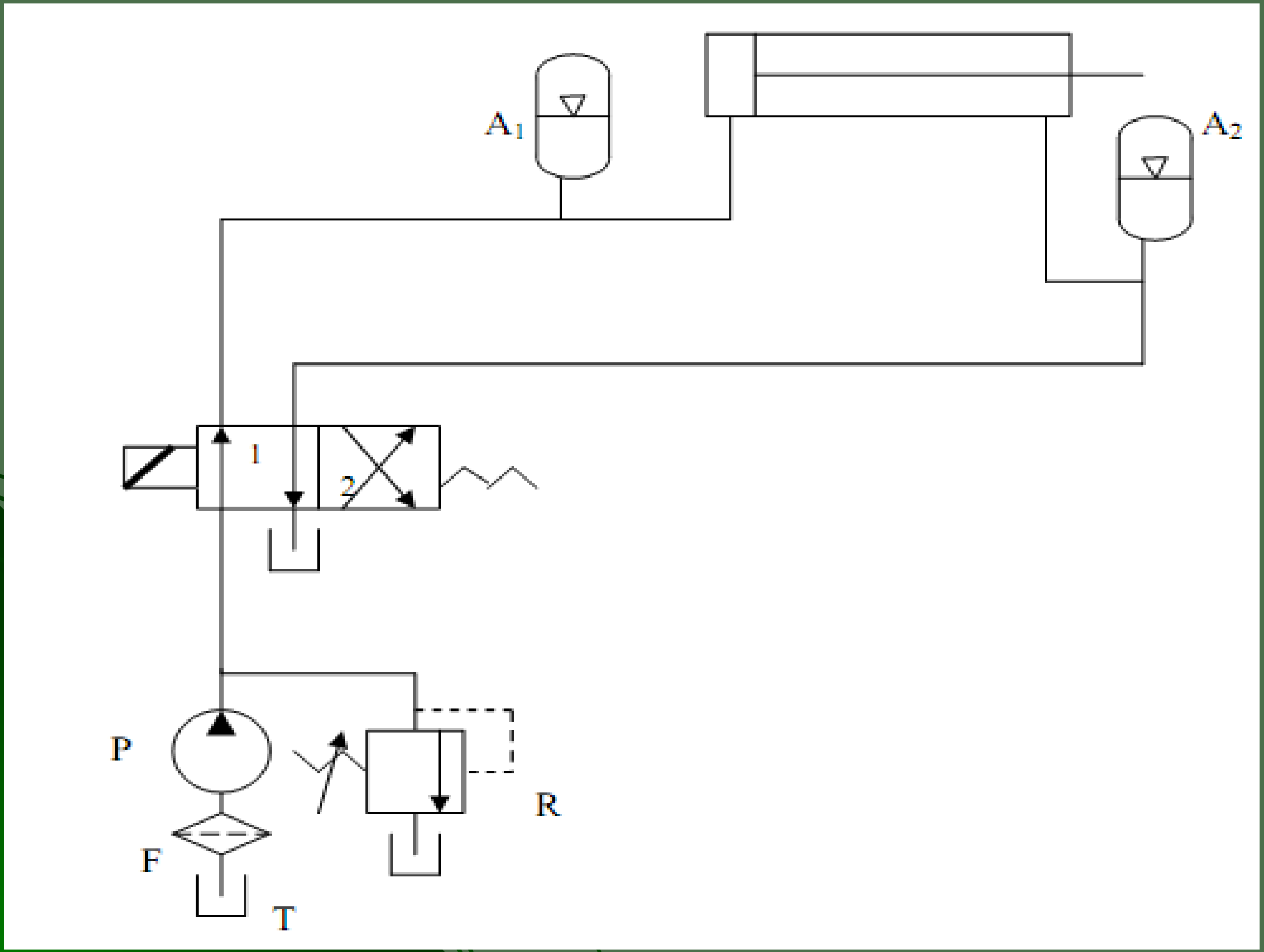
AN AUXILIARY POWER SOURCE



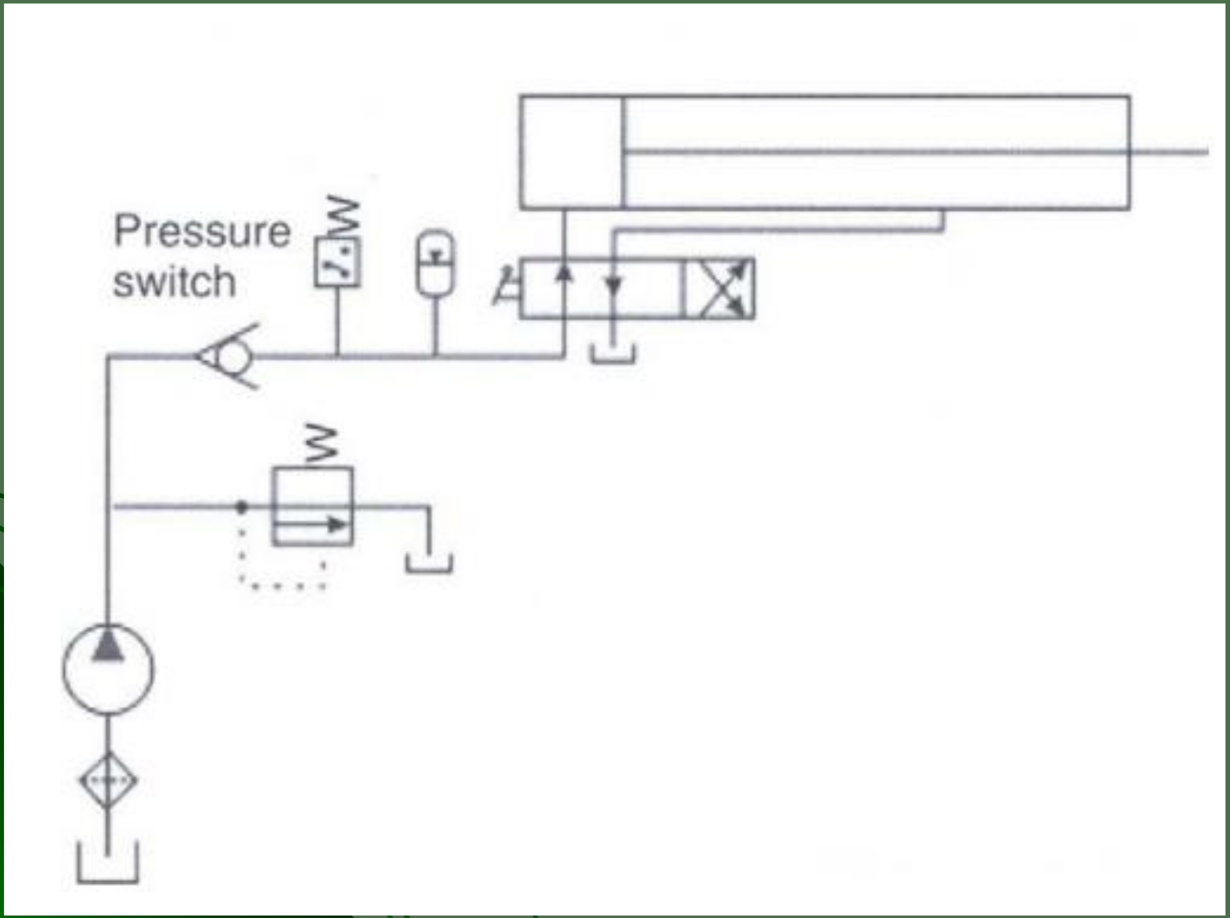
ACCUMULATOR AS AN EMERGENCY POWER SOURCE



ACCUMULATOR AS A HYDRAULIC SHOCK ABSORBER



ACCUMULATOR AS A LEAKAGE COMPANSATOR



HYDRAULICS AND PNEUMATICS

PART – B

UNIT – 5

MAINTENANCE OF HYDRAULIC SYSTEM

HYDRAULIC FLUID

- Hydraulic fluid is the most important component of any hydraulic system. It serves as a lubricant, heat transfer medium, sealant and most important of all, a means of energy transfer.

DESIRABLE PROPERTIES OF HYDRAULIC OIL

1. Ideal viscosity
2. Good lubricity
3. Low volatility
4. Non-toxicity
5. Low density
6. Environmental and chemical stability
7. High degree of incompressibility
8. Fire resistance
9. Good heat-transfer capability
10. Foam resistance and most importantly
11. Easy availability and cost-effectiveness.

- 1. Ideal viscosity.
- 2. Good lubrication capability.
- 3. Demulsibility.
- 4. Good chemical and environmental stability.
- 5. Incompressibility.
- 6. Fire resistance.
- 7. Low flammability.
- 8. Foam resistance.
- 9. Low volatility.
- 10. Good heat dissipation.
- 11. Low density.
- 12. System compatibility.

FIRE RESISTANT FLUID

- A fire resistant fluid is one that can be ignited but will not support combustion when the ignition source is removed.

TYPES OF FIRE RESISTANT FLUIDS

- Water – glycol solutions
- Water – in – oil emulsions
- Straight synthetics
- High water content fluids

WATER – GLYCOL SOLUTIONS

- This type consists of 40% water and 60% glycol.
- These solutions have high viscosity index values, but the viscosity raises as the water evaporates.
- The operating temperature range runs from -23°C and 83°C.
- Most of the newer synthetic seal materials are compatible with water glycol solutions.
- However, metal such as Zinc, Cadmium, and Magnesium react with water glycol solutions and therefore should not be used.

WATER – IN – OIL EMULSIONS

- This type consists of about 40% water completely dispersed in a special oil base.
- It is characterized by the small droplets of water completely surrounded by oil.
- The water provides a good coolant property but tends to make the fluid more corrosive.
- The operating temperature range runs from -23°C and 83°C.
- These fluids are compatible most rubber seal materials found in petroleum based hydraulic system.

STRAIGHT SYNTHETICS

- This type is chemically formulated to inhibit combustion and in general has the highest fire – resistant temperature.
- Typical fluids in this category are the phosphate esters or chlorinated hydrocarbons.
- Disadvantage of straight synthetic include low viscosity index, incompatibility with most natural or synthetic rubber seals, and high costs.
- In particular, the phosphate ester readily dissolve paints, pipe thread compounds, and electrical insulation.

HIGH WATER CONTENT FLUIDS

- This type consists of about 90% water and 10% concentrate.
- The concentrate consist of fluid additives that improve viscosity, lubricity, rust protection, and protection against bacteria growth.
- Advantage of high water content fluids include high fire resistance, outstanding cooling characteristics, and low cost which is about 20% of the cost of petroleum based hydraulic fluid.

GENERAL TYPE OF FLUIDS

- PETROLIUM - BASED FLUIDS
- LUBRICATING OILS
- AIR

Types of Hydraulic Fluids

1. Petroleum-based fluids
2. Emulsions -Oil-in-water emulsions

   - Water-in-oil emulsions

4. Synthetic fluids
5. Vegetable oils

PETROLIUM - BASED FLUIDS

- It is the most widely used type of oil.
- Additives should be added to these fluid in order to maintain the following properties,

- Good lubricity
- High viscosity index
- Oxidation resistance

- The primary disadvantage is that it is flammable.

LUBRICATING OILS

- These are conventional engine type oil.
- Due to their better lubricating properties, they enhance the life of the hydraulic components.
- These oils contain anti wear additives used to prevent engine wear on cams and valves.
- Their improved lubricity also provides wear resistance to heavy loaded hydraulic components such as pumps and valves

AIR

The advantages of using air are:

- Air does not burn.
- It can be easily made available in a clean form by the use of filters.
- Any leakage of air from the system is not messy as it simply breaks into the atmosphere.
- Air can also be made into an excellent lubricator by adding a fine mist of oil using a lubricator.
- Use of air in the system eliminates the return lines as air can be simply exhausted back to the atmosphere.

AIR

Air also has certain major disadvantages, some of them being:

- Its compressibility
- Its sluggishness and lack of rigidity
- Its corrosivity on account of the presence of oxygen and water.

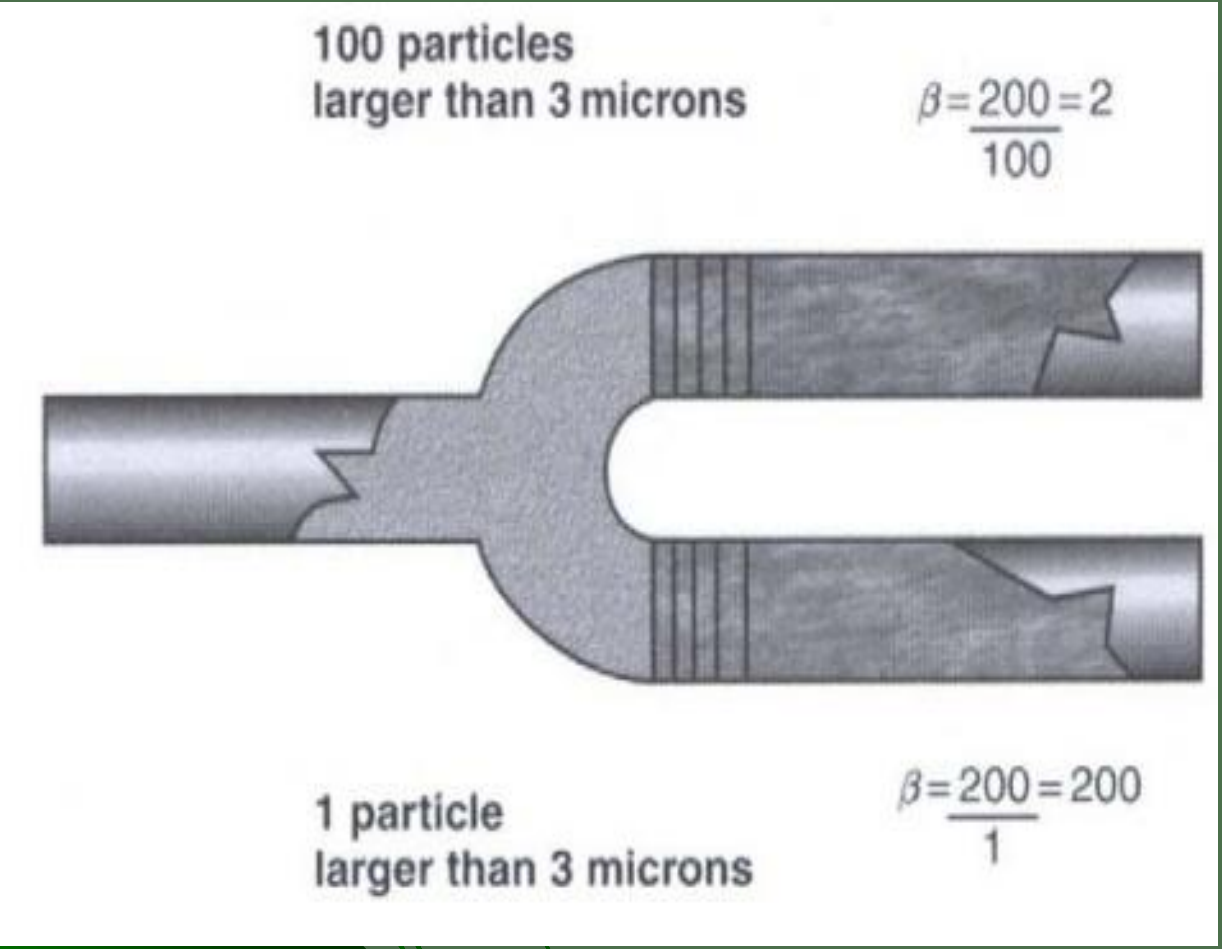
Filters

- A filter is a device whose primary function is to remove insoluble contaminants fluid by the use of porous medium.
- Filter cartridges made of nylon cloth, paper, wire cloth, or fine mesh nylon cloth between layers of coarse wire.
- The particle sizes removed by the filters are measured in microns.
- Filters can remove particles as small as 1 micron.

Beta ratio

- A better parameter for establishing how well a filter traps particles is called the Beta ratio or Beta rating.
- It is a measure of filter's efficiency. It is defined as the number of particles upstream from the filter that are larger than the micron rating of the filter, divided by the number of particles downstream from the filter larger than the micron ratings of the filter.

Beta ratio



100 particles
larger than 3 microns
β = 200 / 100 = 2
1 particle
larger than 3 microns
β = 200 / 1 = 200

Beta ratio

- The beta ratio for the filter at top is given by

  β=200/100=2 which is a less efficient value, whereas the beta ratio for the filter at the bottom is given by β=200/1=200 which is more efficient value.

Beta efficiency

$$\text{Beta efficiency} = \frac{\text{No. of upstream particles} - \text{No. of downstream particles}}{\text{No. of upstream particles}}$$

$$\text{Beta efficiency} = 1 - 1\sqrt{\text{Beta ratio}}$$

For example a filter with a beta ratio of 40 would have an efficiency of 1/40 = 97.5%.

The higher the beta ratio, higher is the beta efficiency.

Filtration methods

- Mechanical
- Absorbent
- Adsorbent

Mechanical

- This type normally contains a metal or cloth screen or a series of metal disks separated by thin spacers.
- These are capable of removing only relatively coarse particles from the fluid.

Absorbent

- These filters are porous and permeable materials such as paper, wood pulp, diatomaceous earth, cloth, cellulose, and asbestos.

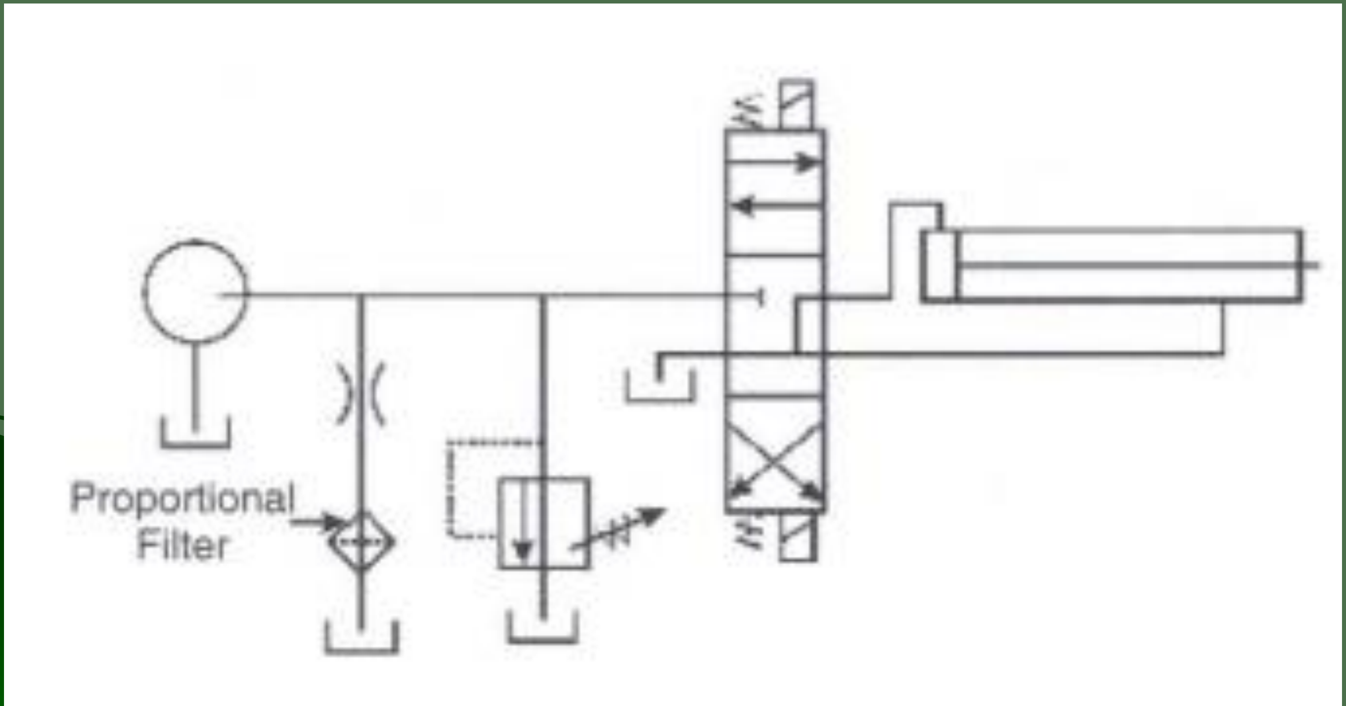
Adsorbent

- Adsorbent is a surface phenomenon and refers to the tendency of particles to cling to the surface of the filter.
- Adsorbent materials used include activated clay and chemically treated paper.

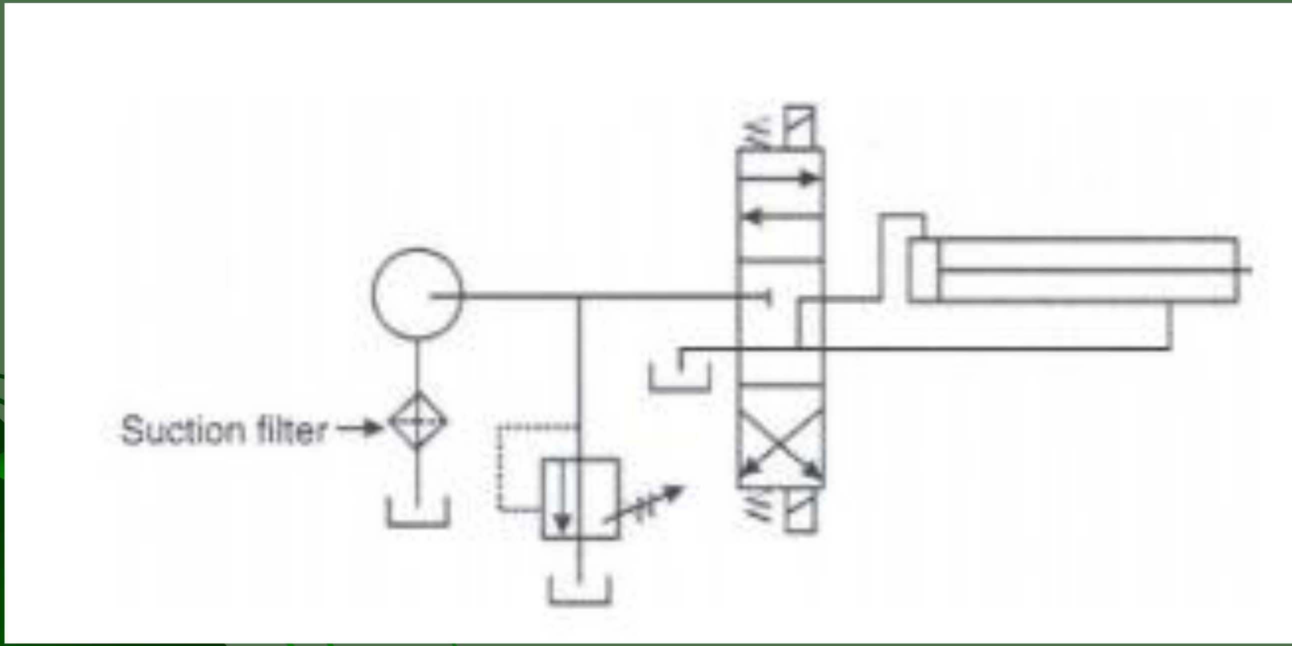
Filter locations

- proportional flow filter in a separate drain line
- Full flow filter in suction line
- Full flow filter in pressure line
- Full flow filter in return line

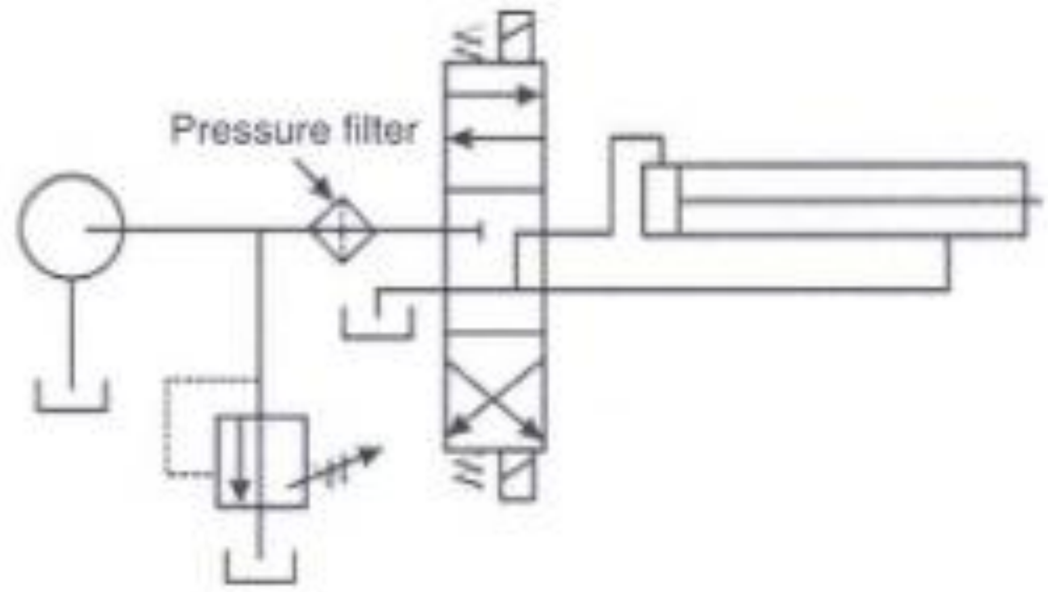
Proportional flow filter in separate drain line



Full flow filter in suction line

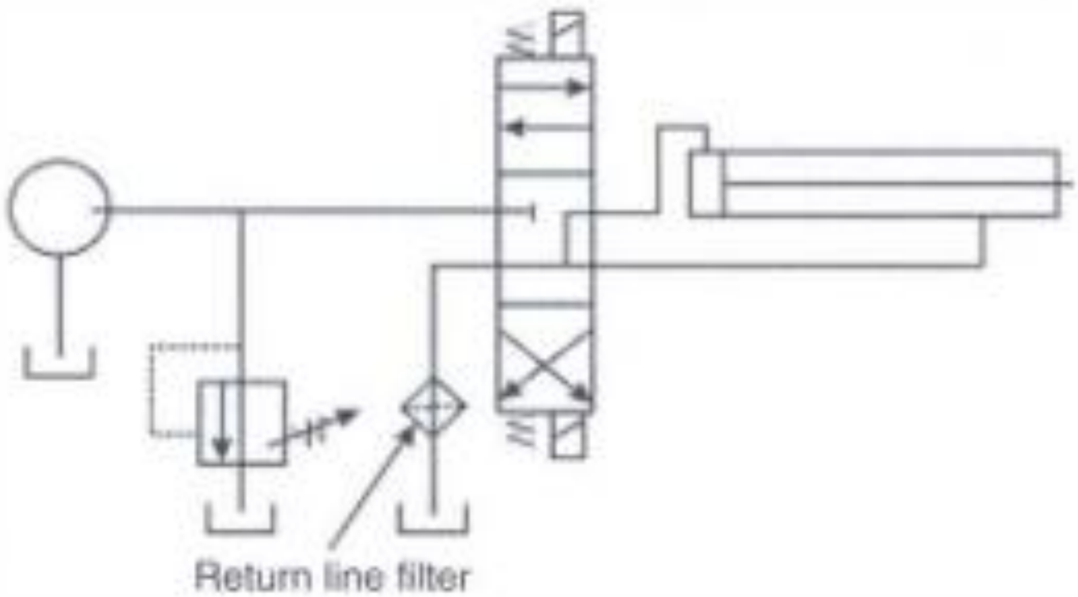


Full flow filter in pressure line



Full flow filter in pressure line

Full flow filter in return line

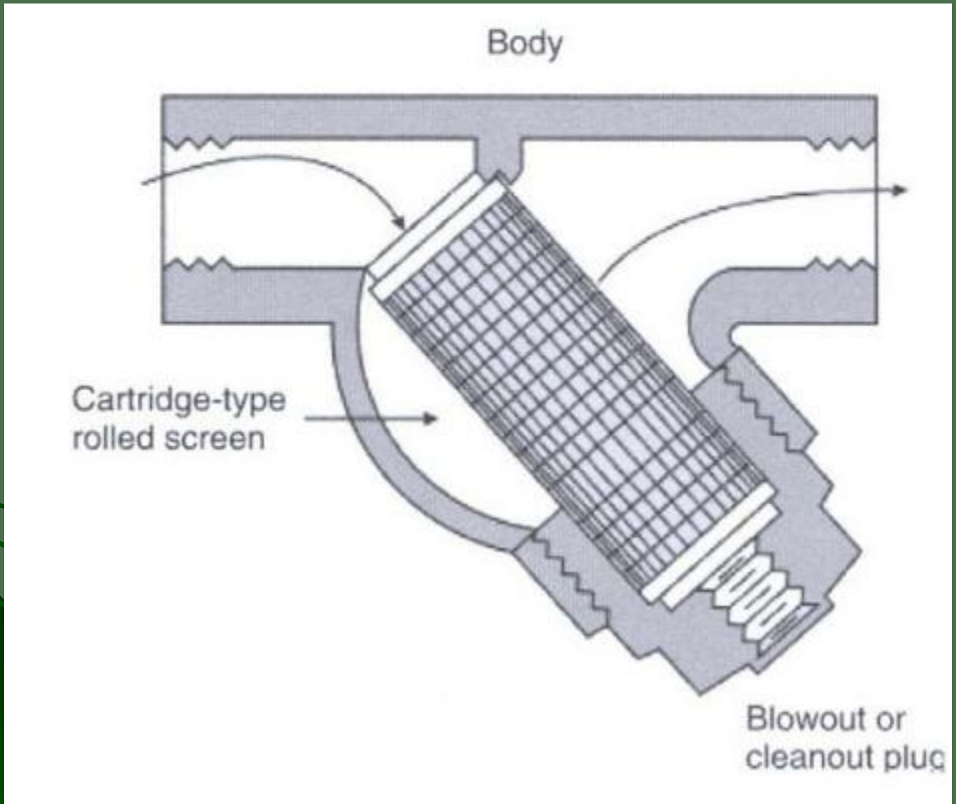


Full flow filter in return line

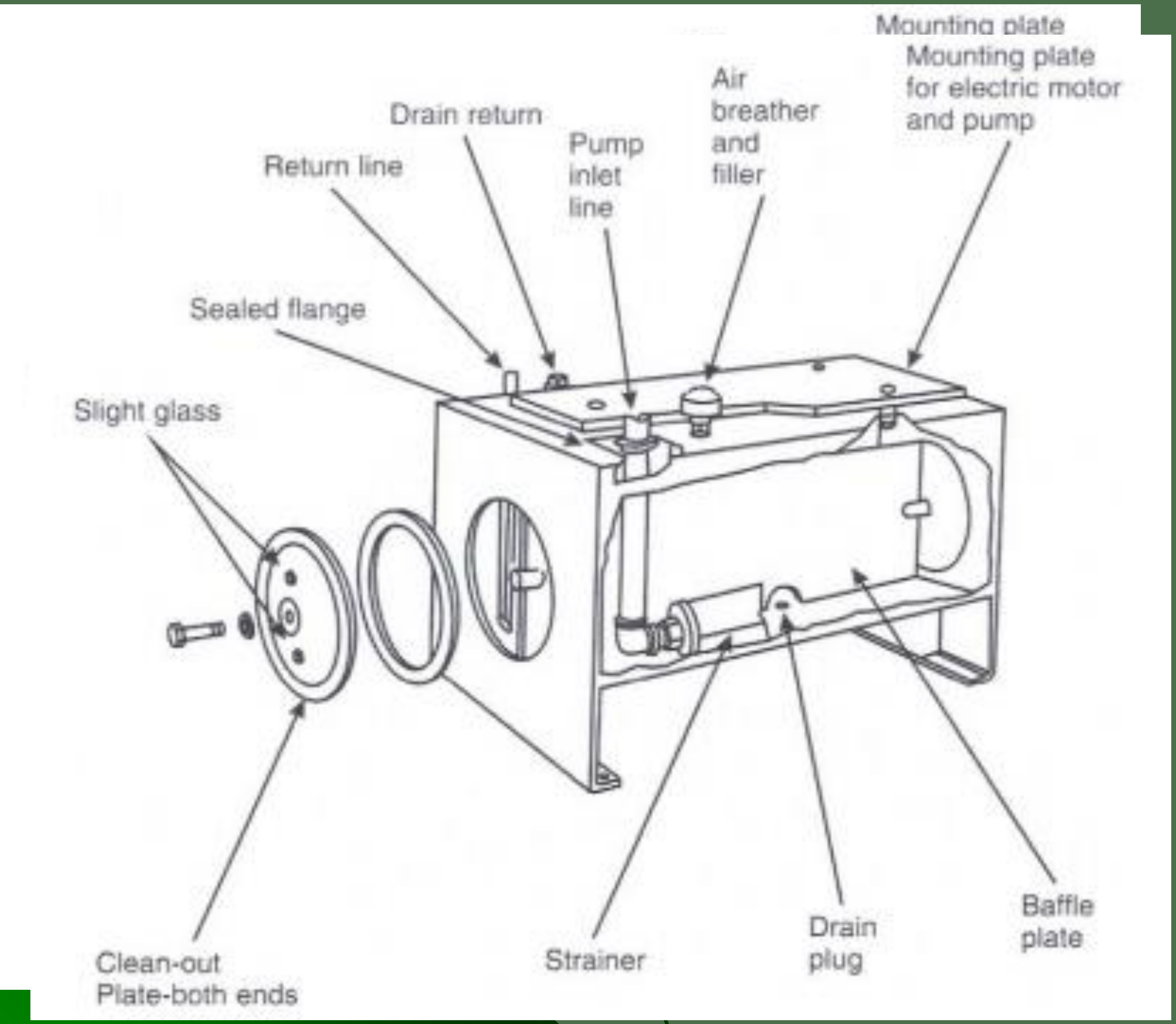
Strainer

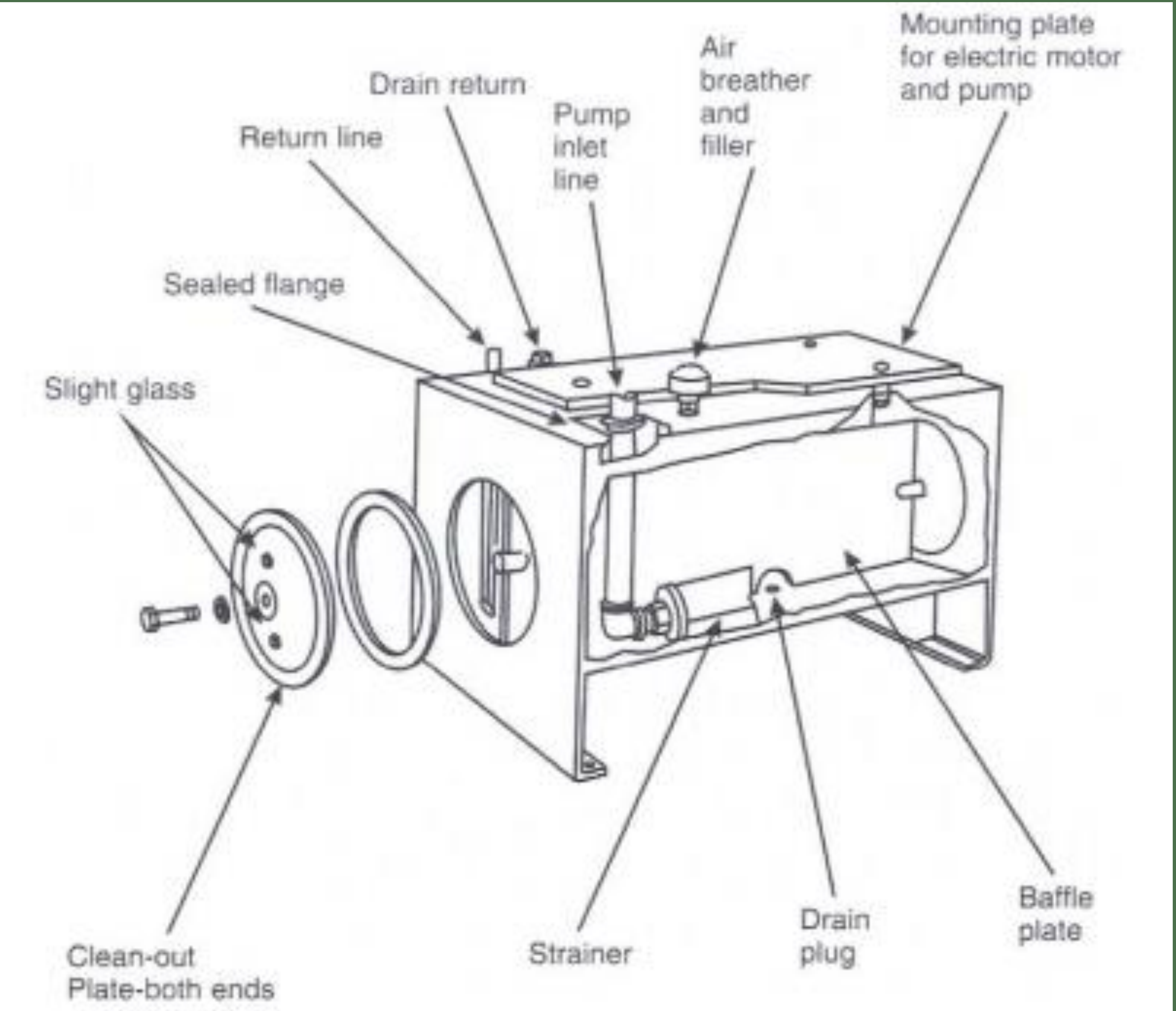
- A strainer is a device made of wire mesh screens, which seek to remove large solid particles from a fluid.
- A common strainer design uses two screens, in cylindrical shape.
- One cylinder is inside the other and two are separated by a small gap.
- The outer cylinder is a coarse mesh screen and inner one is a fine screen mesh.

Strainer

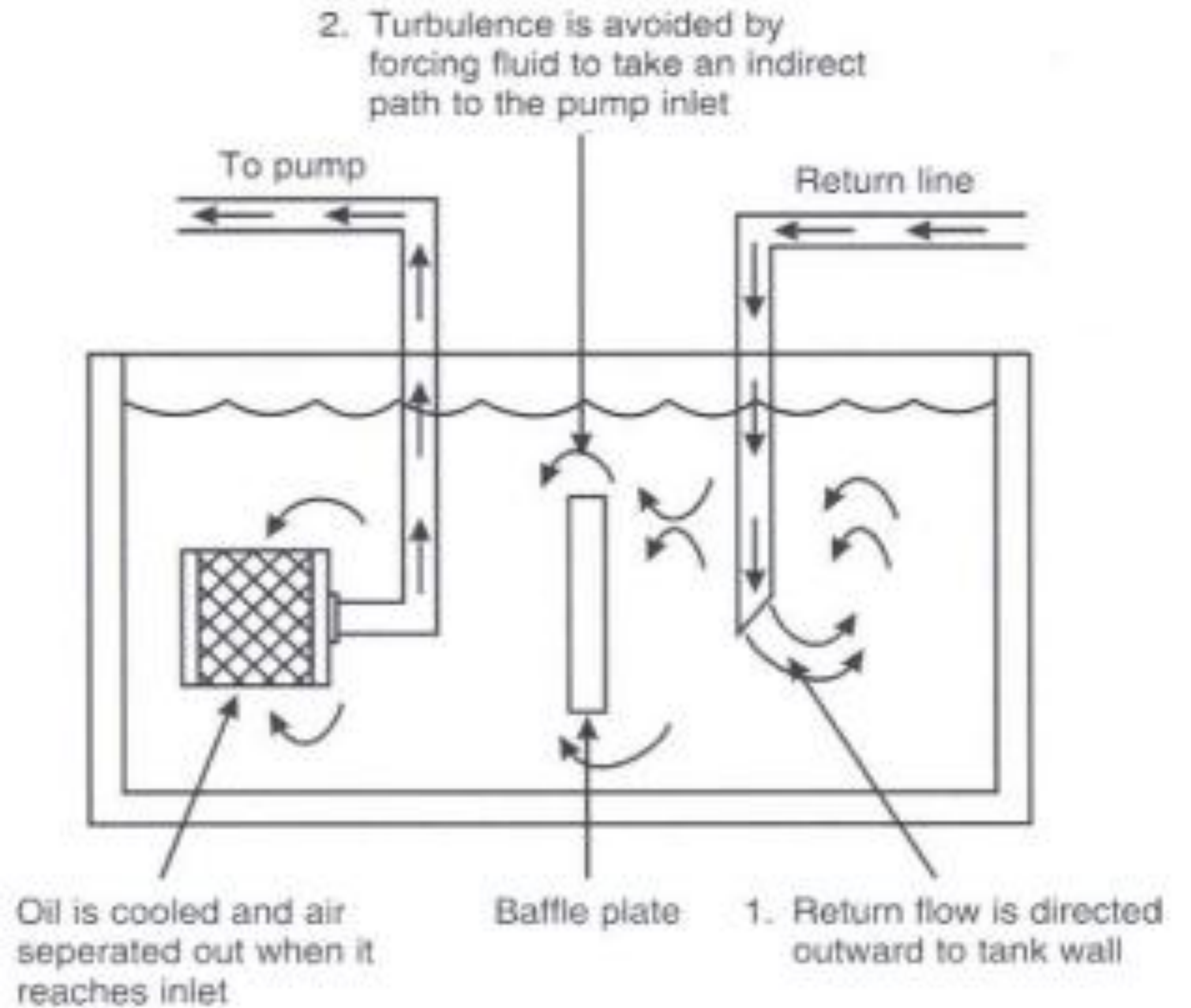

Body
Cartridge-type
rolled screen
Blowout or
cleanout plug

Reservoir system





Mounting plate for electric motor and pump
Air breather and filler
Drain return
Pump inlet line
Return line
Sealed flange
Slight glass
Clean-out Plate-both ends
Strainer
Drain plug
Baffle plate



2. Turbulence is avoided by forcing fluid to take an indirect path to the pump inlet
To pump
Return line
Oil is cooled and air seperated out when it reaches inlet
Baffle plate
1. Return flow is directed outward to tank wall

Types of reservoirs

- Non – pressurized reservoir
- Pressurized reservoir

Non – pressurized reservoir

- As the name suggests this type of reservoir is not pressurized, which means, the pressure in the reservoir will at no point of time above that of atmospheric pressure.
- These reservoirs are vent to air to ensure that the pressure within, does not rise above the atmospheric pressure.

Sizing of reservoir

- It should have sufficient volume and space to allow the dirt and metal chips to settle and the air to escape freely.
- It should be capable of holding all the fluid that might be drained from the system.
- It should be able to maintain the fluid level high enough to prevent air escaping into the pump suction line.
- The surface area of the reservoir should be large enough to dissipate the heat generated by the system.
- It should have sufficient free board over the fluid surface to allow thermal expansion of the fluid.

Pressurized reservoir

- The required pressure in the reservoir is maintained by means of compressed air. Compressed air is generally introduced into the reservoir from the top at rated pressure of manufacturer.

Causes for hydraulic system break down

- Clogged and dirty oil filters
- Inadequate supply of oil in the reservoir
- Leaking seals
- Loose inlet lines that cause the pump to take in air
- Incorrect type of oil
- Excessive oil temperature
- Excessive oil pressure

Maintenance procedures

1. Maintaining an adequate quantity of clean and proper hydraulic fluid with the correct viscosity
2. Periodic cleaning and changing of all filters and strainers
3. Keeping air out of the system by ensuring tight connections.

sealing devices

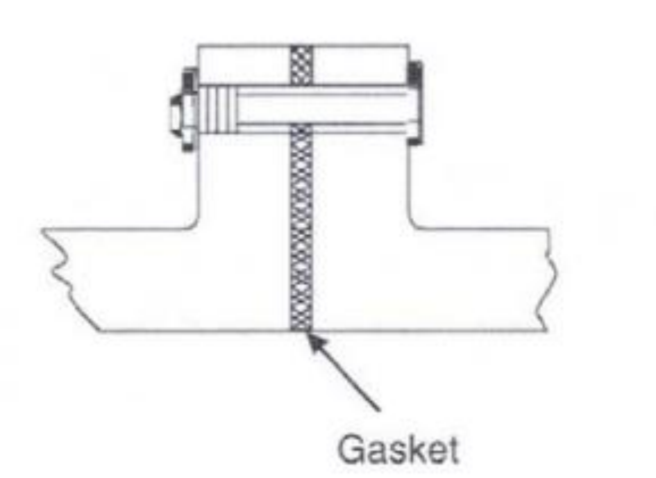
- Seals are used in hydraulic system to prevent excessive internal and external leakages and to keep out contamination.

Sealing devices

- Seals can be of the positive or non positive type and can be designed for static and dynamic applications.
- Positive seals do not allow any leakage whatsoever (external or internal)
- Non – positive seals (such as the clearance used to provide a lubricating film between a valve spool and its housing bore) permit a small amount of internal leakage.

Sealing devices

- Static seals are used between mating parts that are not move relative to each other.
- Which include flange gaskets and seals.
- These seals are compressed between two rigid connected parts.
- These are simple and relatively nonwearing joint



Sealing devices

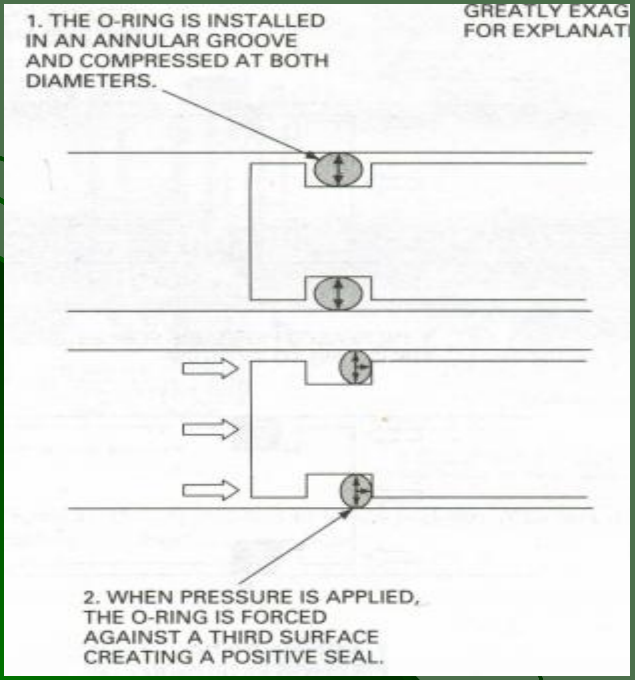
- Dynamic seals are assembled between mating parts that are move relative to each other.
- Hence, dynamic seals are subjected to wear because one of the mating parts rubs against the seal

Most widely used types of seals

- O – rings
- Compression pickings (V – and U – shapes)
- Piston cup packings
- Piston rings
- Wiper rings

O - rings

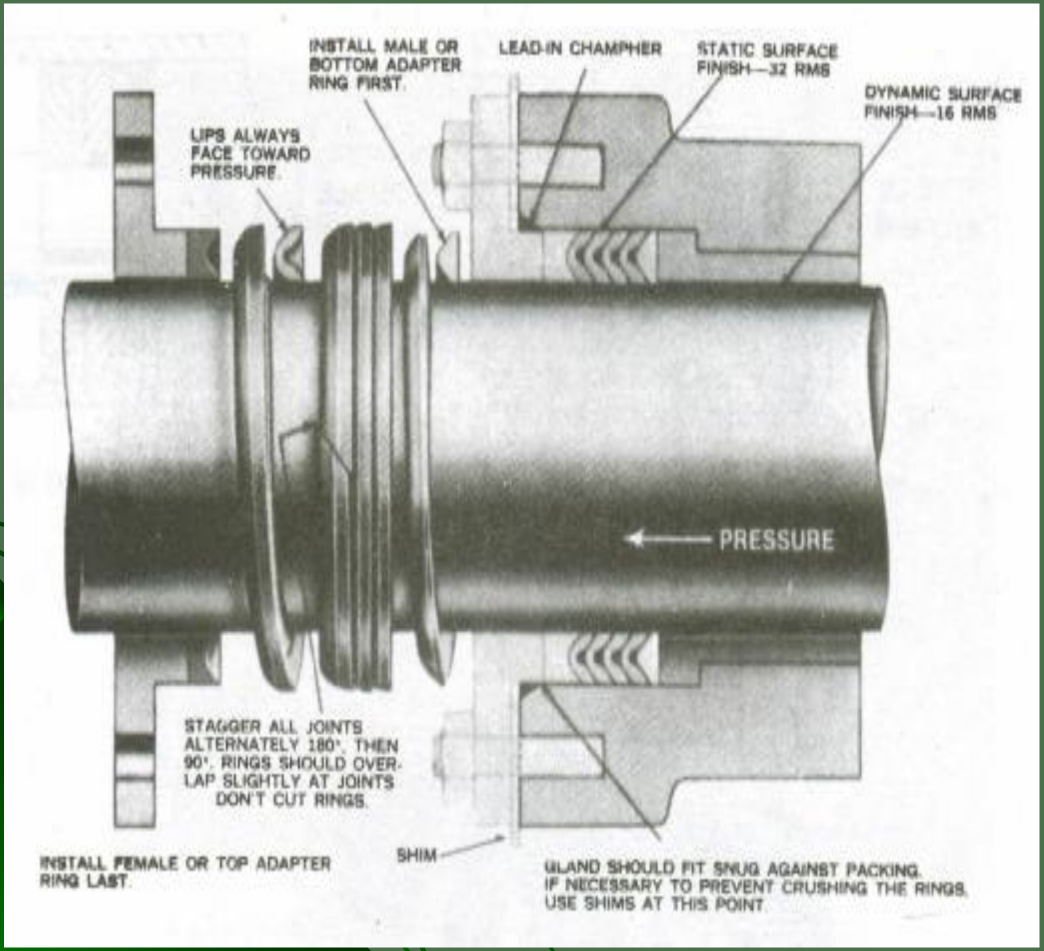
- The O – ring is a one of the most widely used seals for hydraulic system.
- It is a molded synthetic rubber seal that has a round cross section in its free state.



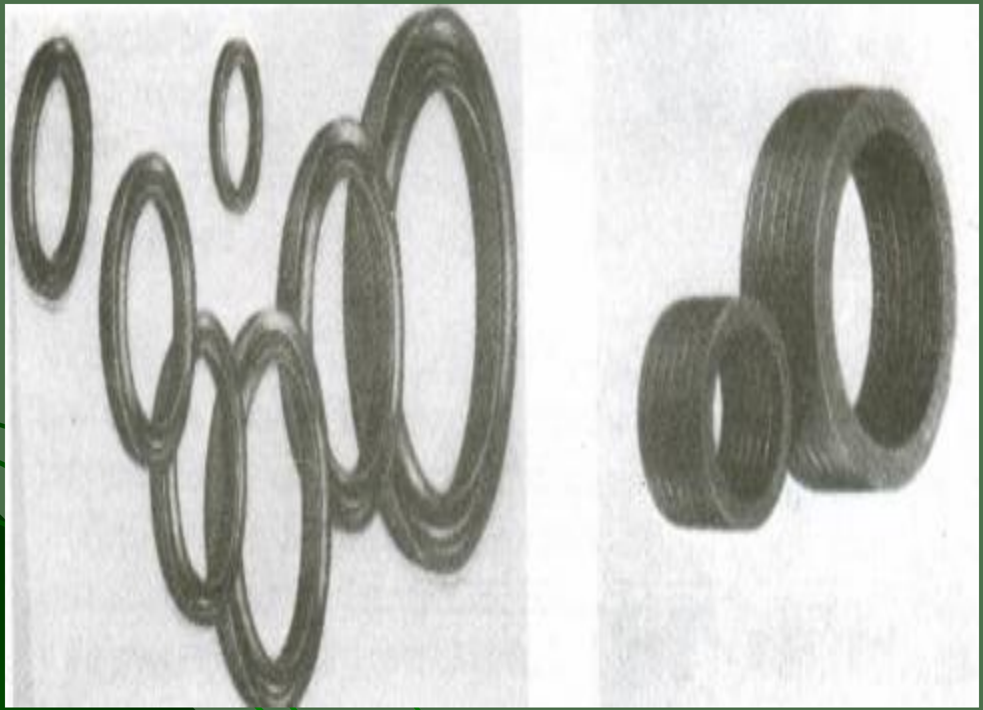
Compression packings (v & U shapes)

- V – ring packings are compression type seals that are used in virtually all types of reciprocating motion applications.
- This include rod and piston seals in hydraulic and pneumatic cylinders, press rams, jacks, and seals on plungers and pistons in reciprocating pumps.
- These packings (which can be molded in U shapes & V shapes) are installed in multiple quantities for more effective sealing.

Compression packings (v & U shapes)

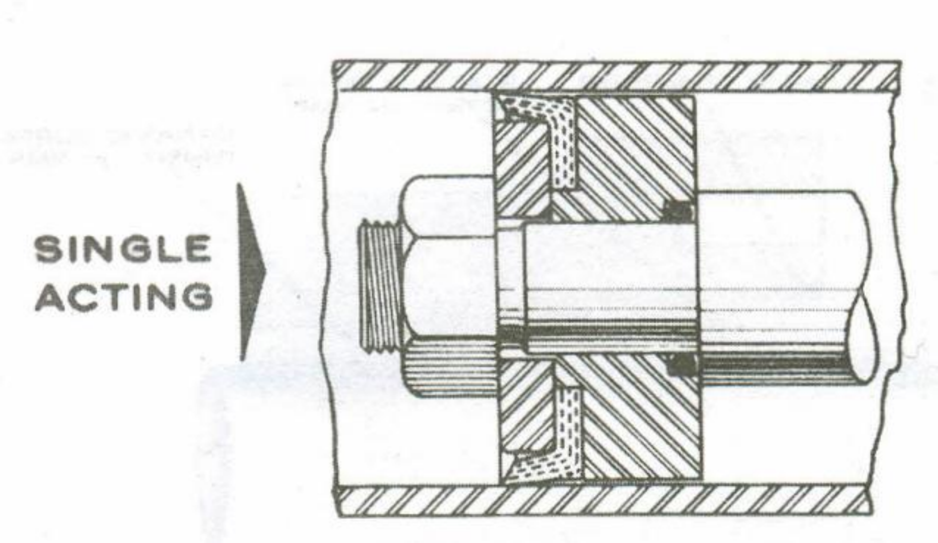


Compression packings (v & U shapes)

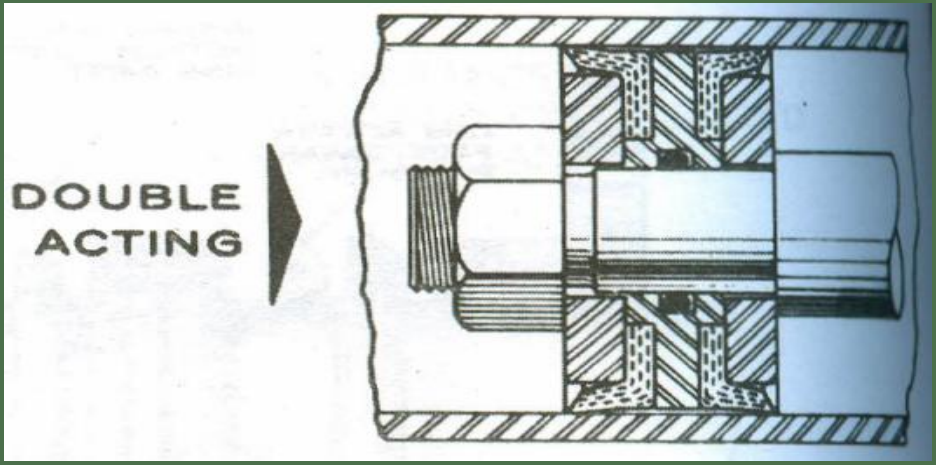


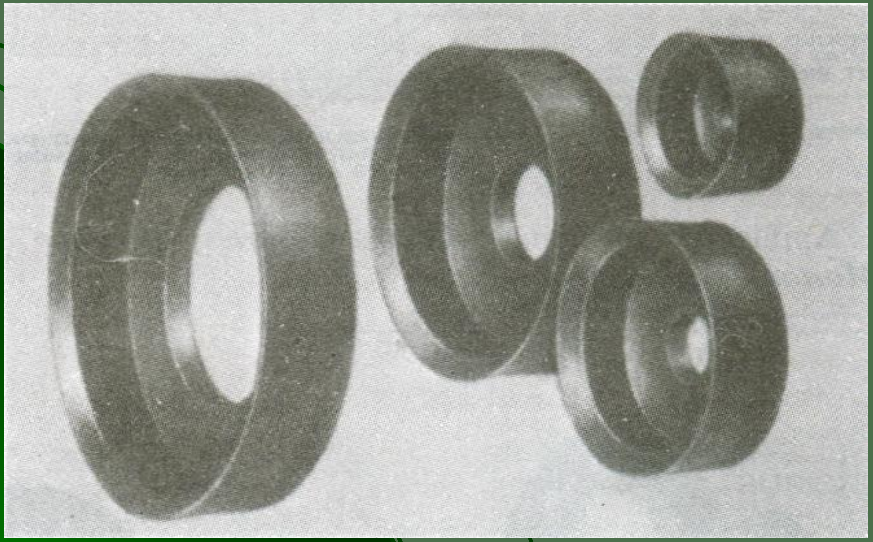
Piston cup packings

- Piston cup packings are designed specially for pistons in reciprocating pumps and pneumatic and hydraulic cylinders.



Piston cup packings

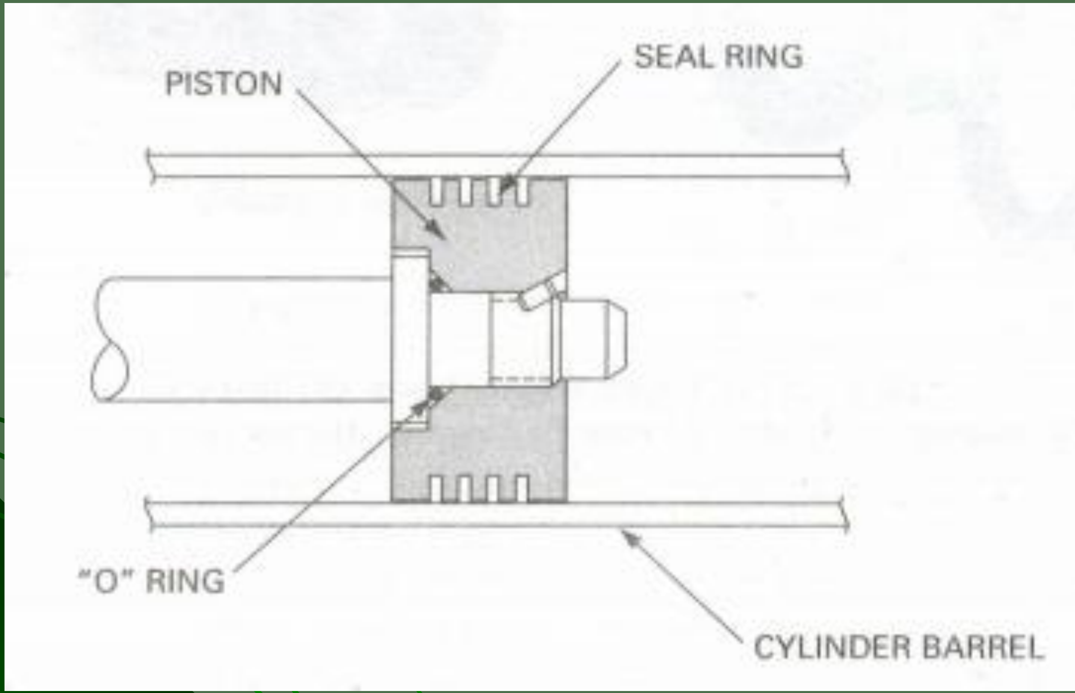




Piston rings

- Piston rings are seals that are universally used for pistons.
- Metallic piston rings are made of cast iron or steel and are usually plated or given an outer coating to prevent rusting and corrosion.
- Non metallic piston rings are made out of terafluoroethylene (TFE), a chemically inert, tough, waxy solid.
- Their extremely low coefficient of friction permits them to be run completely dry and at the same time prevents scoring of the cylinder wall.
- Applications where the presence of lubrication can be dangerous. For instant in an oxygen compressor, just a trace of oil is a fire or explosion hazard.

Piston rings



Wiper rings

- Wiper rings are seals designed to prevent foreign abrasive or corrosive materials from entering a cylinder.
- They are not designed to seal against pressure.

Wear of moving parts due to solid particle contamination of fluid

- One major problem caused by solid contaminants is that they prevent the hydraulic fluid from providing proper lubrication of moving internal parts such as pumps, hydraulic motors, valves and actuators.
- There are three relative sizes of solid contaminants
- Smaller than
- Equal to
- And larger than

Problems caused by gases in hydraulic fluid

- **Gases can be present in a hydraulic fluid in three ways**
- Free air
- Entrained gas
- Dissolved air

Free air

- Air can exist in a free pocket located at some high point of a hydraulic system (such as highest elevation of a given pipeline)

- This free air either existed in the system when it was initially filled or was formed due to air bubbles in the hydraulic fluid rising into the free pocket.

Problems due to free air

- Free air can cause the hydraulic fluid to posses a much lower stiffness (bulk modulus), resulting in spongy and unstable operation of hydraulic actuator.

Entrained gas

- **Entrained gas (gas bubble within the hydraulic fluid) is created in two ways**

- Air bubbles can be created when the flowing hydraulic fluid sweeps air out of a free pocket and carries it along the fluid stream.

- Entrained gas also occur when the pressure drops below the vapor pressure of the hydraulic fluid.

Entrained gas

- Vapor pressure defined as the pressure at which a liquid starts to boil (vaporize) and thus being changing into a vapor (gas).

- The vapor pressure of a hydraulic fluid (or any other liquid) increases with an increase in temperature.

Problems due to entrained gas

- Entrained gases can cause cavitation problems in pumps and valves.
- Entrained gases can also greatly reduce the hydraulic fluid’s effective bulk modulus, resulting in spongy and unstable operation of hydraulic actuators.

Dissolved air

- Dissolve air is in solution and thus cannot be seen an does not add to the volume of the hydraulic fluid.
- A hydraulic fluid, as received at atmospheric pressure, typically contains about 6% of dissolved air by volume.
- After the hydraulic fluid is pumped, the amount of dissolved air increases to about 10% by volume.

Dissolved air

- Dissolved air creates no problem in hydraulic system as long as the air remains dissolved.
- However if the dissolved air comes out of solution, it forms bubbles in the hydraulic fluid and thus becomes entrained air.
- The amount of air that can be dissolved in the hydraulic fluid increases with pressure and decreases with temperature.
- Thus, dissolved air will comes out of solution as the pressure decreases or the temperature increases.

Probable causes of hydraulic system problem

- NOISY PUMP

  - Air entering pump inlet
  - Misalignment of pump and drive unit
  - Excessive oil viscosity
  - Dirty inlet strainer
  - Chattering relief valve
  - Damaged pump
  - Excessive pump speed
  - Loose or damaged inlet line

Probable causes of hydraulic system problem

- <u>LOW OR ERRATIC PRESSURE</u>

- Air in the fluid
- Pressure relief valve set too low
- Pressure relief valve not properly seated
- Leak in hydraulic line
- Defective or worn pump
- Defective or worn actuator

Probable causes of hydraulic system problem

- NO PRESSURE

- Pump turning in wrong direction
- Ruptured hydraulic line
- low oil level in reservoir
- Broken pump shaft
- full pump flow bypassed to tank due to faulty valve or actuator

Probable causes of hydraulic system problem

- ACTUATOR FAIL TO MOVE

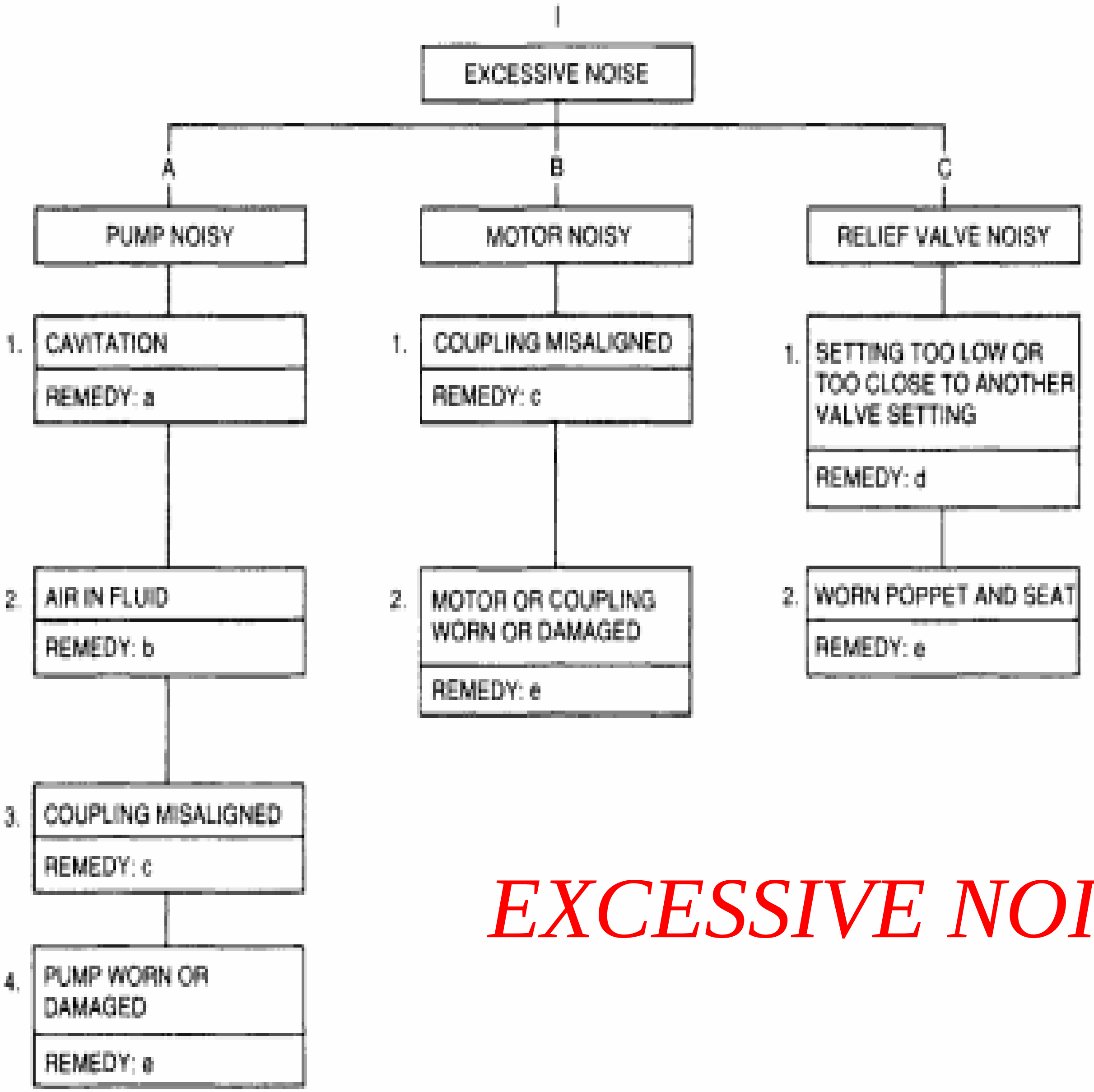
- Faulty pump
- Directional control valve fail to shift
- System pressure too low
- Defective actuator
- Pressure relief valve stuck open
- Actuator load is excessive
- Check valve in backwards

Probable causes of hydraulic system problem

- <u>SLOW OR ERRATIC MOTION OF ACTUATOR</u>
- Air in system
- Viscosity of fluid too high
- Worn or damaged pump
- Pump speed too low
- Excessive leakage through actuators or valves
- Faulty or dirty flow control valve
- Blocked air breather in reservoir
- Low fluid level in reservoir
- Faulty check valve

Probable causes of hydraulic system problem

- <u>OVER HEATING OF HYDRAULIC FLUID</u>
- Heat exchanger turned off or faulty
- Undersized components or spring
- Incorrect fluid
- Continuous operation of pressure relief valve
- Overloaded system
- Dirty fluid
- Reservoir too small
- Inadequate supply of oil in reservoir
- Excessive pump speed



EXCESSIVE NOISE

Trouble shooting

- <u>EXCESSIVE NOISE</u>

a) Any or all of the above

- Replace dirty filter and clean strainers, clogged inlet line and reservoir breather.
- Change fluid, switch over to proper pump speed and overhaul.

b) Any or all of the above

- Fill reservoir to required level, bleed air from the system plug leakages in inlet line.
- Replace pump shaft seal/ shaft.

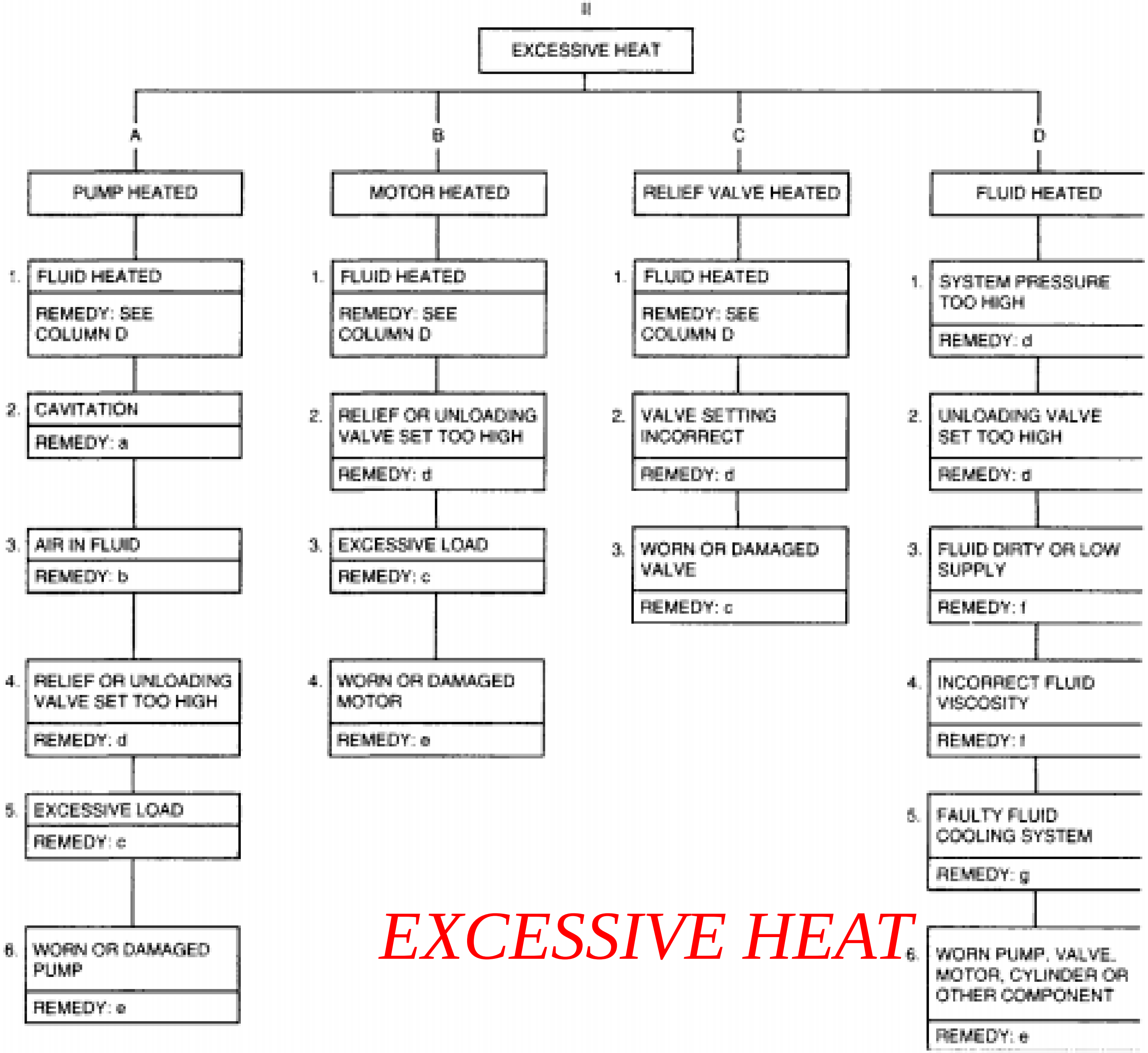
Trouble shooting

c) Condition of bearings, seals and couplings, to be checked and the unit aligned.

d)Pressure to be corrected.

e)Overhaul or replace.

EXCESSIVE HEAT



Trouble shooting

- <u>EXCESSIVE HEAT</u>

a) Any or all of the above

- Replace dirty filter and clean strainers, clogged inlet line and reservoir breather.
- Change fluid, switch over to proper pump speed and overhaul.

b) Any or all of the above

- Fill reservoir to required level, bleed air from the system plug leakages in inlet line.
- Replace pump shaft seal/ shaft.

Trouble shooting

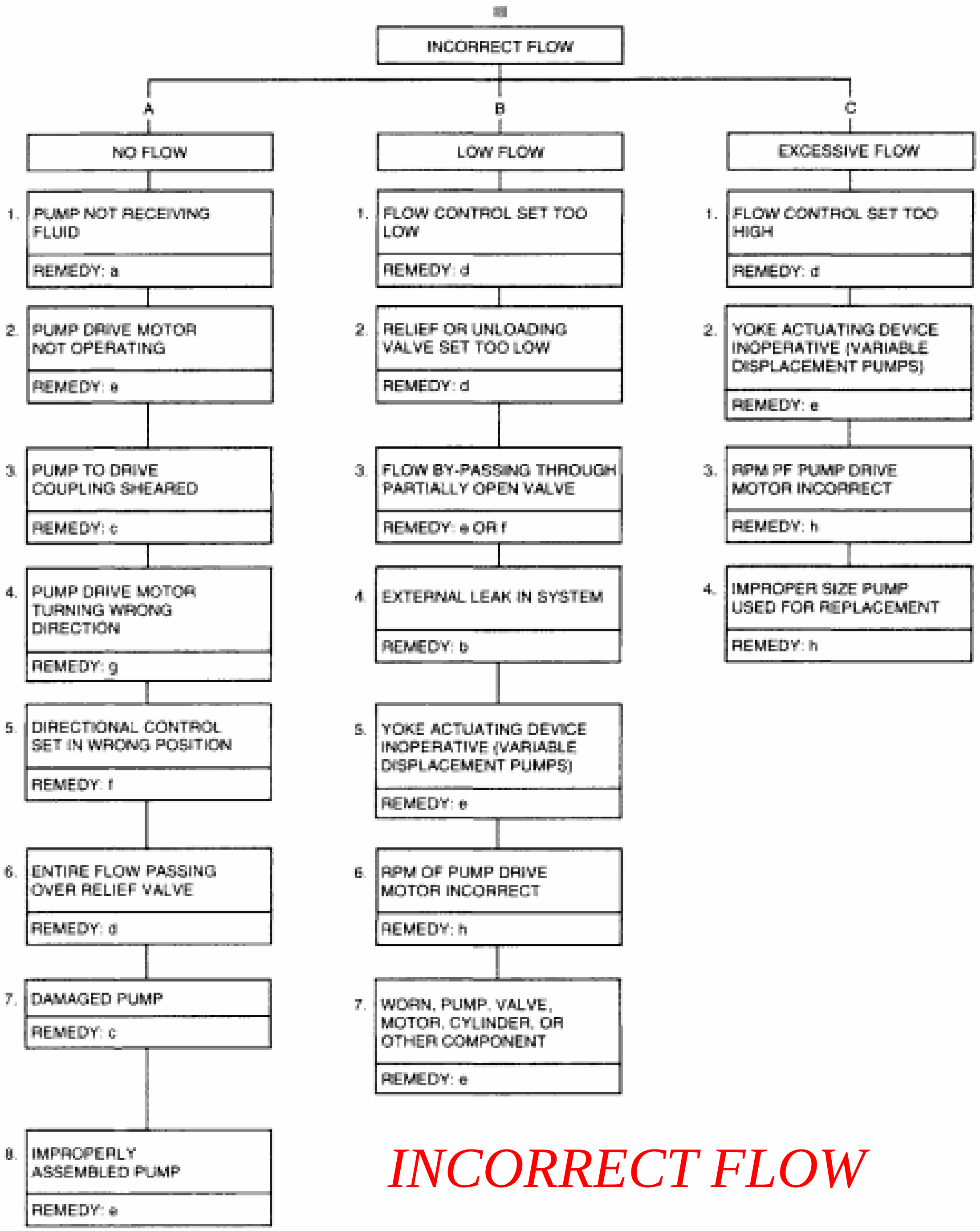
c) Condition of bearings, seals and couplings, to be checked and the unit aligned.

d) Pressure to be corrected.

e) Overhaul or replace.

f) Filters to be replaced and hydraulic fluid to be changed in the event of improper fluid viscosity.

g) Clean cooler and cooler strainer, replace cooler control valve or repair or replace cooler.



INCORRECT FLOW

Trouble shooting incorrect flow

a) Any or all of the following

1) Replace the dirty filter and clean clogged inlet line and reservoir breather.
2) Change fluid, switch over to proper pump speed and overhaul/replace.

b) Tighten leaky connections and carryout bleeding of the system.

c) Check for pump or pump drive dame. Replace and align coupling.

Trouble shooting for incorrect flow

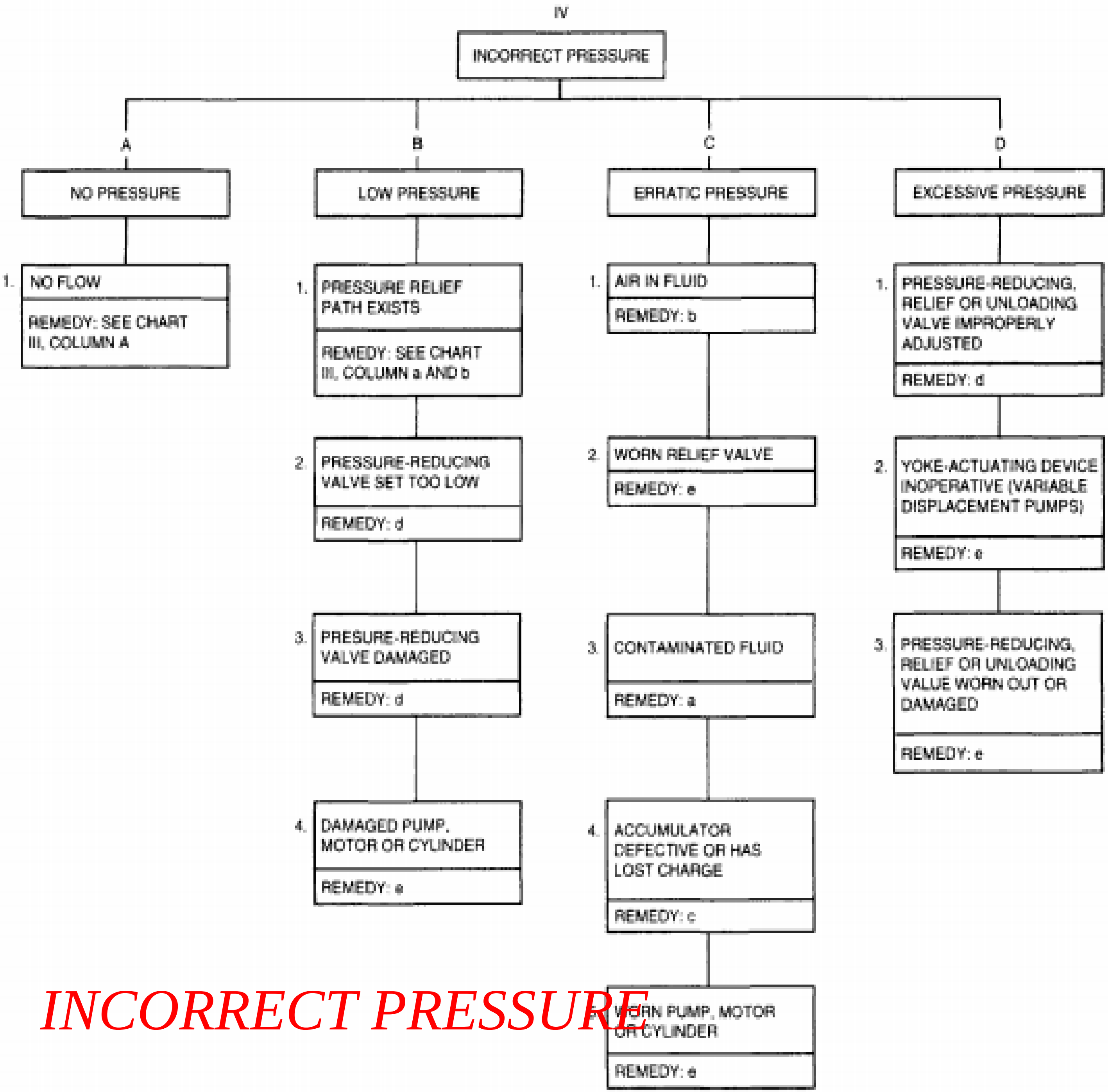
d) Adjust

e) Overhaul or replace

f) Check position of manually operated controls, check electrical circuit of solenoid controls.

g) Reverse the direction of rotation.

h) Replace with correct unit.



INCORRECT PRESSURE

Trouble shooting incorrect pressure

- INCORRECT PRESSURE

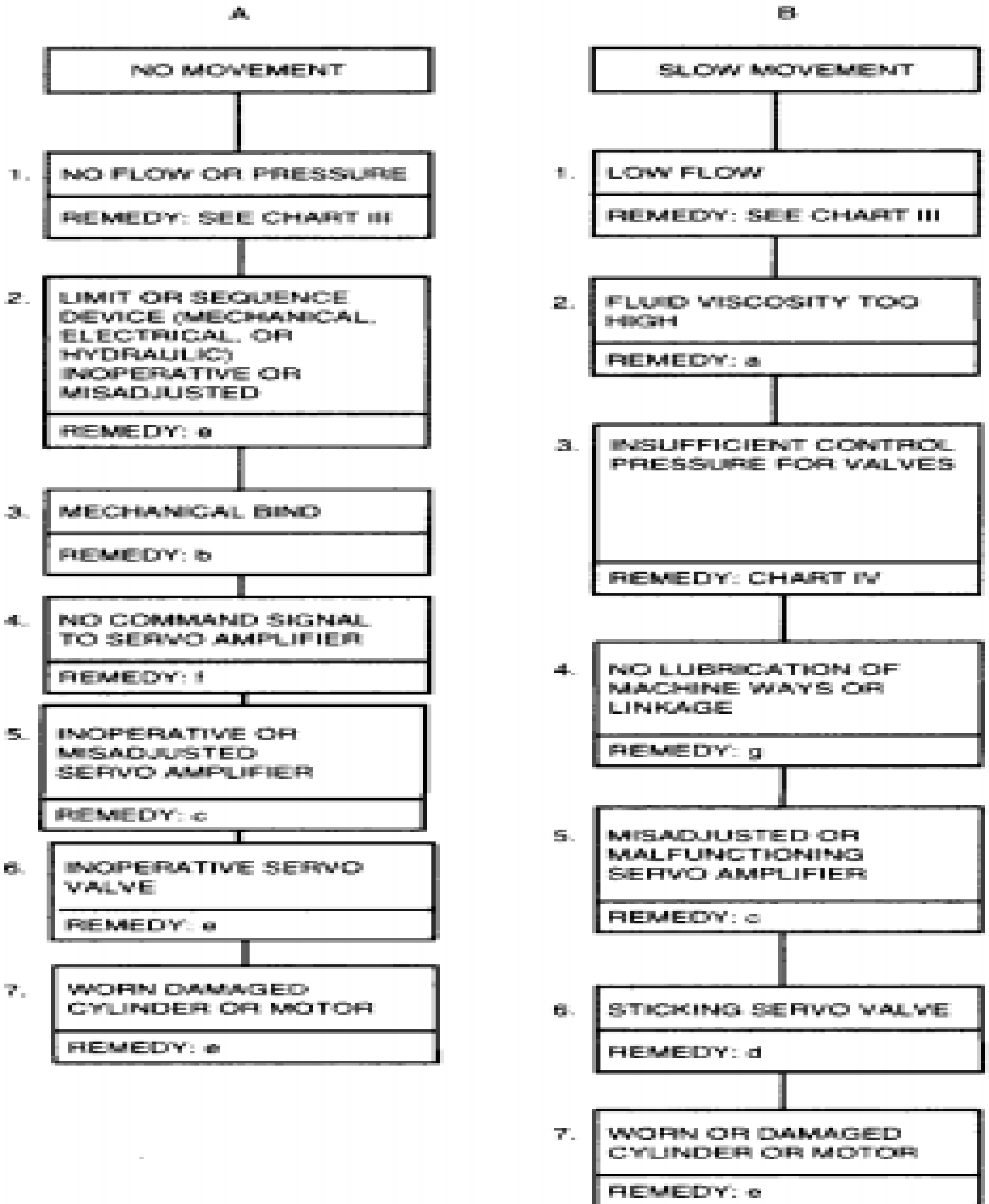
a) Change dirty filters. Replace hydraulic fluid.

b) Tighten leaky connections, fill reservoir to proper level and carry out bleeding of the system.

c) Gas valve to be checked for leakage charged to correct pressure and overhauled if defective.

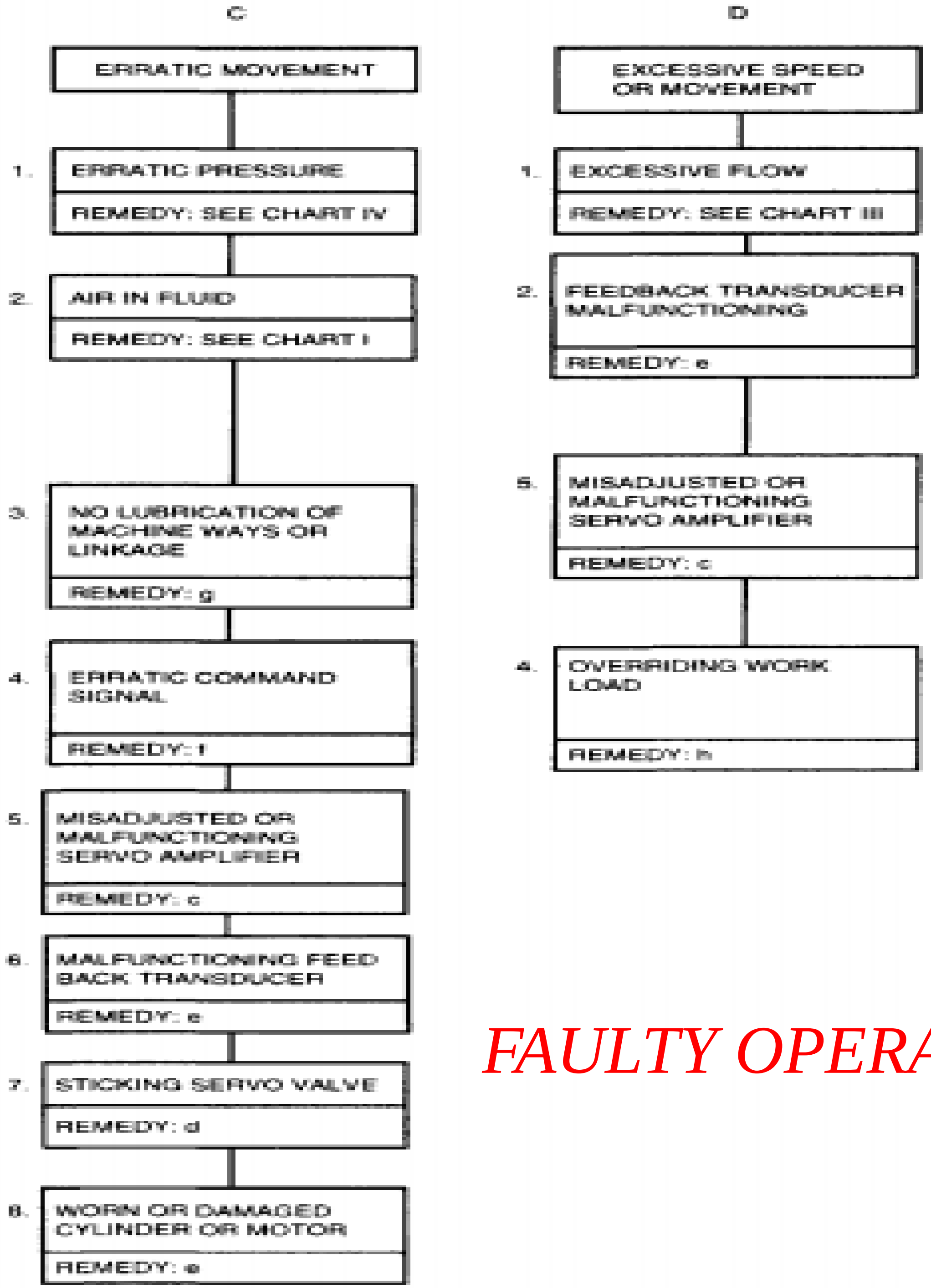
d) Adjust

e) Overhaul or replace



FAULTY OPERATIONS

FAULTY OPERATION



Trouble shooting for faulty operations

- <u>FAULTY OPERATION</u>

a)Cold state of the fluid. Viscosity of the fluid also to be checked and if found improper replaced with fluid having correct viscosity.

b)Locate bind and repair.

c)Adjust repair or replace.

d)Clean adjust or replace. Check system fluid condition and also condition of filters.

e)Repair command/console interconnecting wires.

f)Lubricate.

g)Adjust, repair, or replace counterbalance valve.

PART - B

UNIT – 6

INTRODUCTION TO PNEUMATIC CONTROL

INTRODUCTION TO PNEUMATIC CONTROL

The word ‘Pneuma’ means breath or air. Pneumatics is application of compressed air in automation. In Pneumatic control, compressed air is used as the **working medium,** normally at a pressure from 6 bar to 8 bar. Using Pneumatic Control, maximum force up to 50 kN can be developed. Actuation of the controls can be manual, Pneumatic or Electrical actuation. **Signal medium** such as compressed air at pressure of 1-2 bar can be used [Pilot operated Pneumatics] or Electrical signals [D.C or A.C source- 24V – 230V] can be used [Electro pneumatics]

ADVANTAGES OF PNEUMATIC SYSTEM

- wide availability of air
- Cheaper
- Cleaner
- Compressibility of air
- Easy transportation
- Fire proof characteristic
- Simple construction of pneumatic elements and easy handling
- Easier maintenance

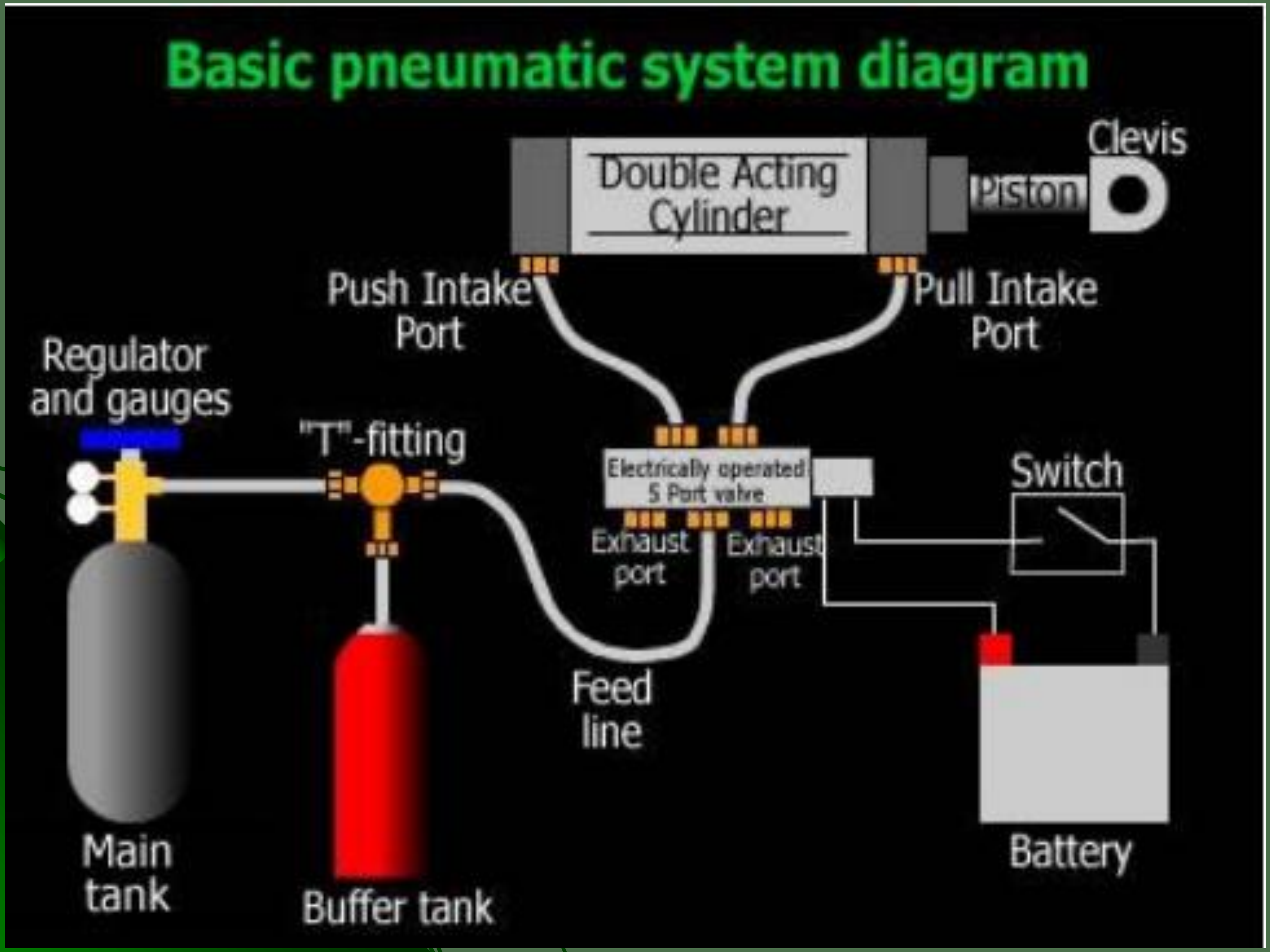
DISADVANTAGES OF PNEUMATIC SYSTEM

- Cost
- Preparation
- Noise Pollution
- Limited Range of Force (only economical up to 50 kN)

APPLICATIONS OF PNEUMATIC SYSTEM

- Drilling Operation
- Turning
- Milling
- Sawing
- Finishing
- Forming
- Quality Control

STRUCTURE OF PNEUMATIC CONTROL SYSTEM



PNEUMATIC ACTUATORS

- Drive Elements are Actuators – used to perform the task of exerting the required force at the end of the stroke or used to create displacement by the movement of the piston.

- Pneumatic Actuators can be classified as

➢ Single Acting Cylinders

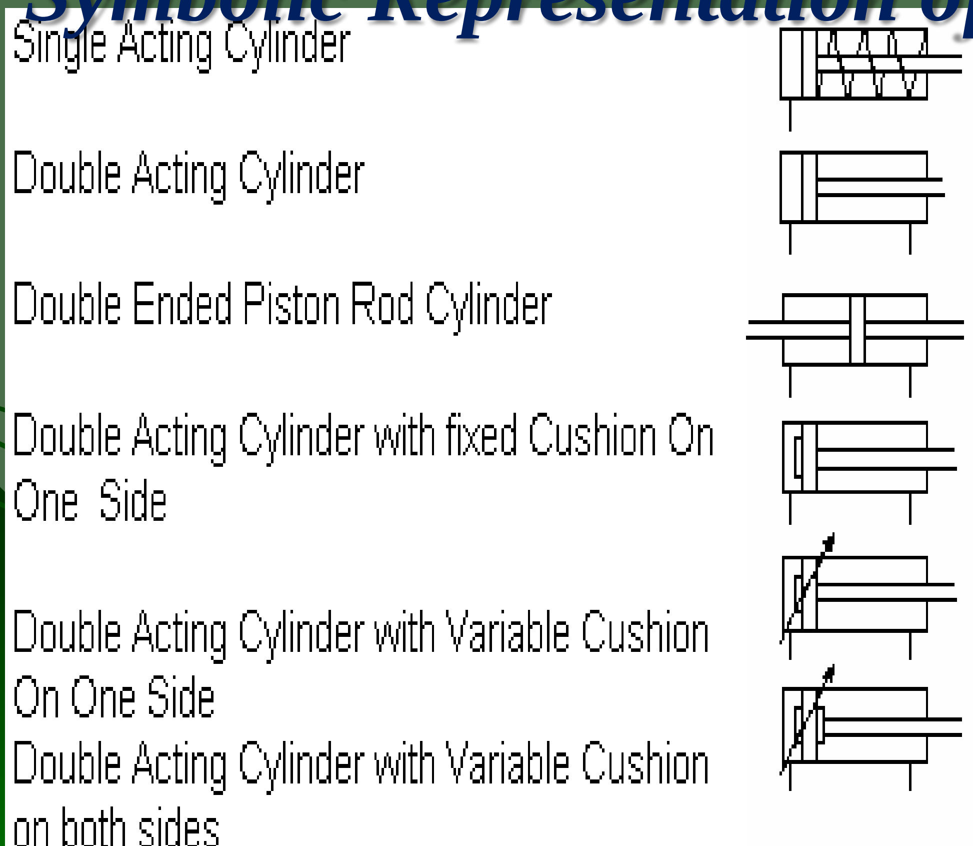
 Conventional Cylinder with Spring Loaded Piston or

 Diaphragm type

➢ Double Acting Cylinders

PNEUMATIC CYLINDERS

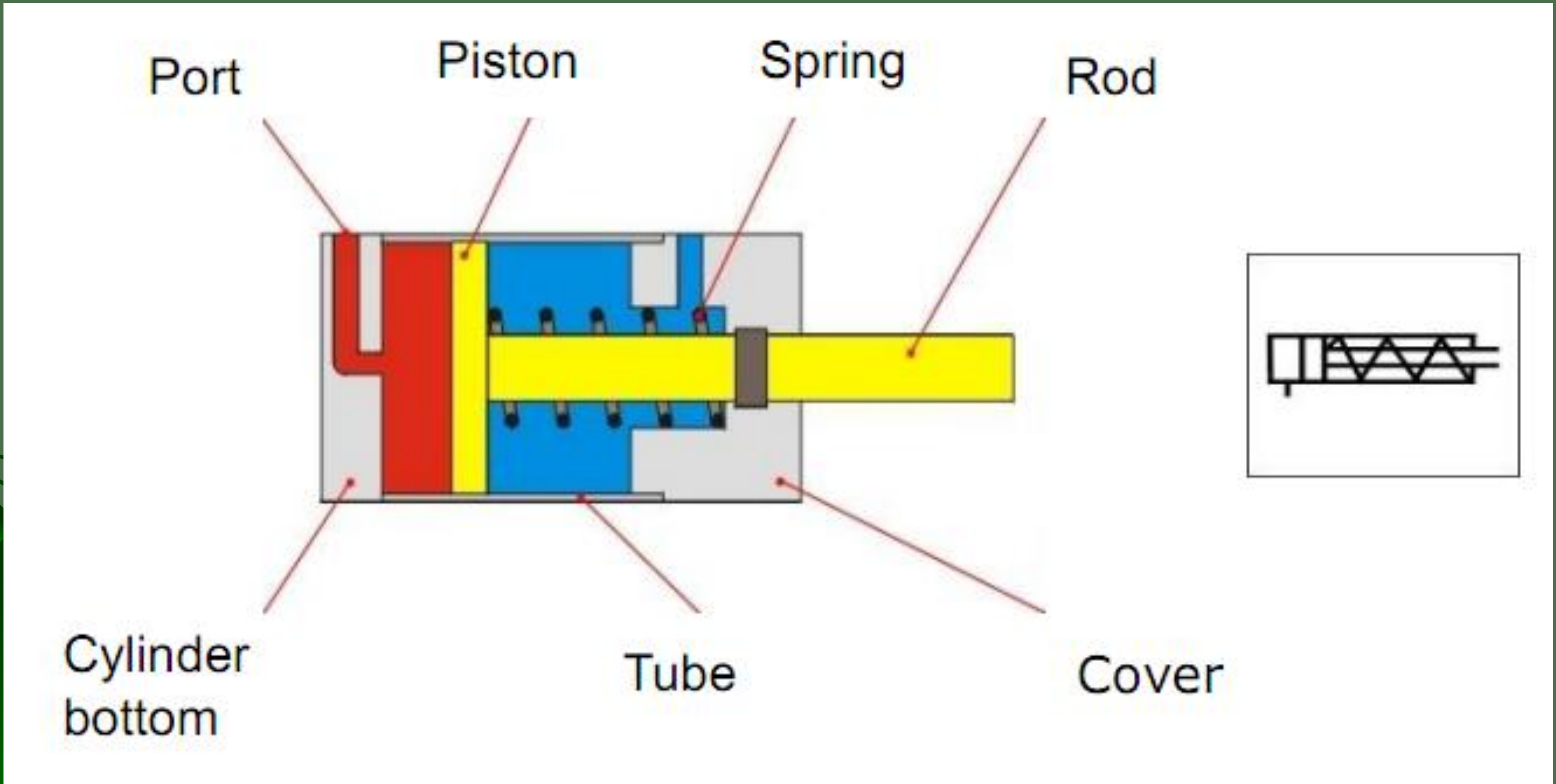
Symbolic Representation of Pneumatic Cylinders -



SINGLE ACTING CYLINDER

- Single acting cylinder has one working port
- Forward motion of the piston is accomplished to due to supply of compressed air behind the piston.
- Return motion of piston takes place only due to built in reset spring placed on the rod side of the cylinder.
- Single acting cylinders are used for applications such as clamping, feeding, sorting, locking, ejecting, braking etc., where force is required to be exerted only in one direction..
- Single acting cylinder are usually available in short stroke lengths [maximum length up to 80 mm] due to the natural length of the spring.
- Single Acting Cylinder exert force only in one direction.

SINGLE ACTING CYLINDER

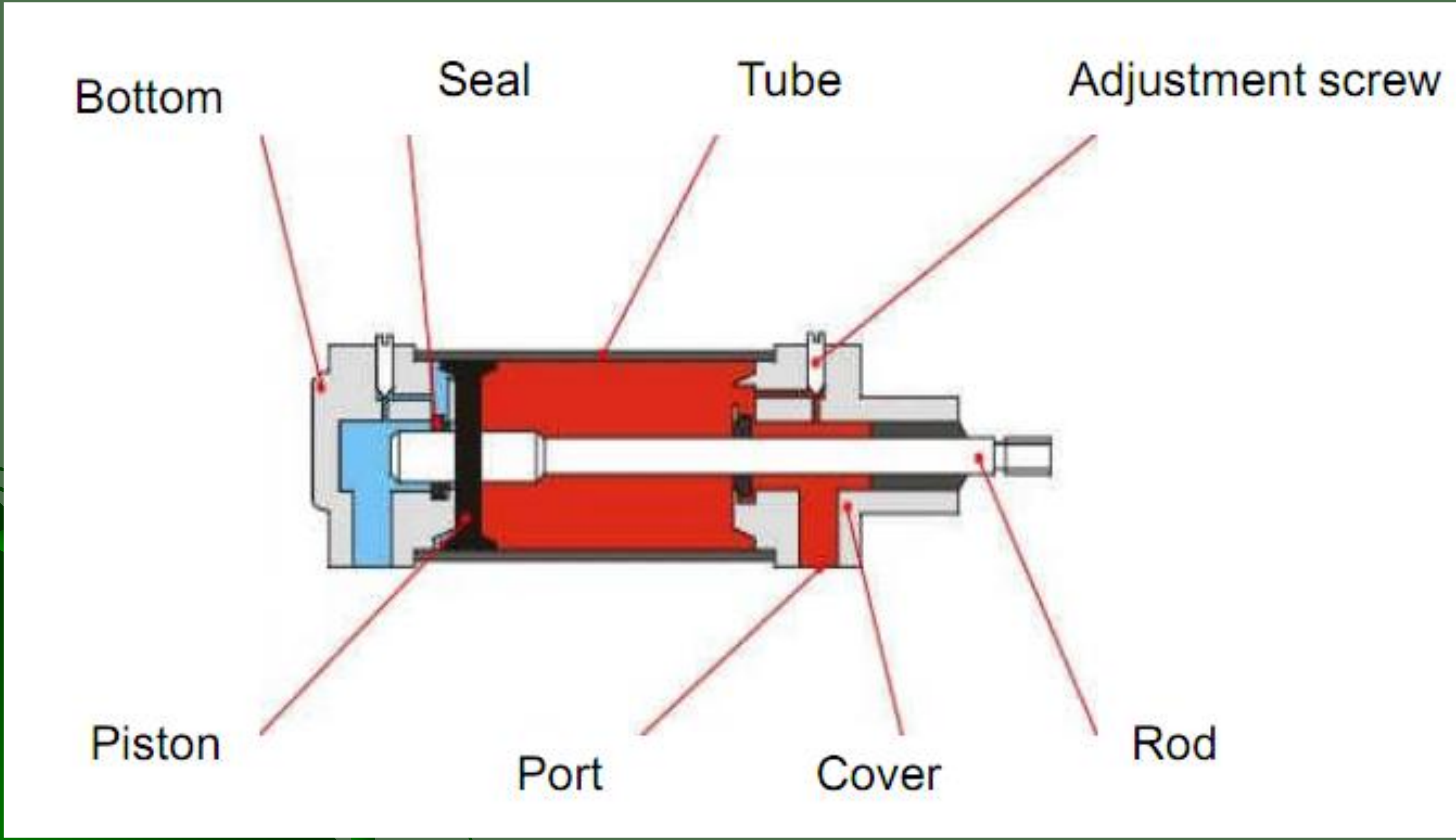


DOUBLE ACTING CYLINDERS

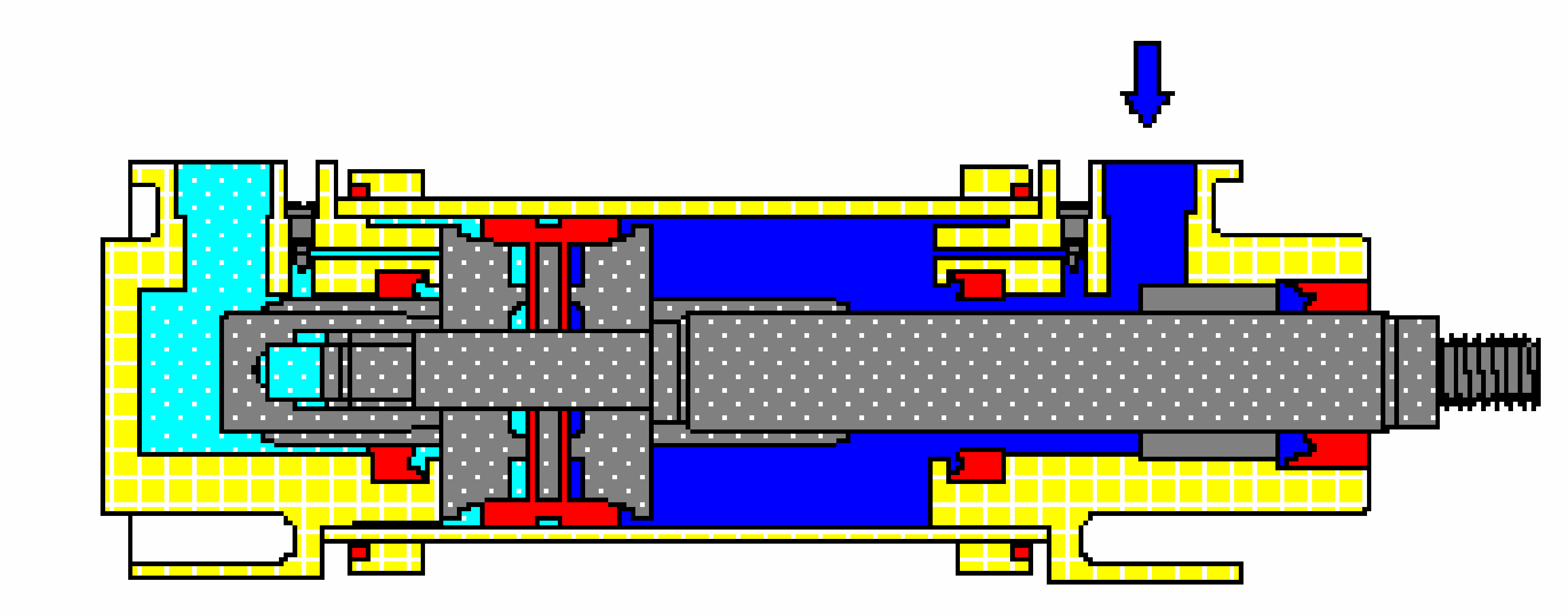
They are available in different constructions such as

- Conventional,
- Double ended piston rod type,
- Rod less type
- Tandem type
- Multi-position type and
- Rotary type..

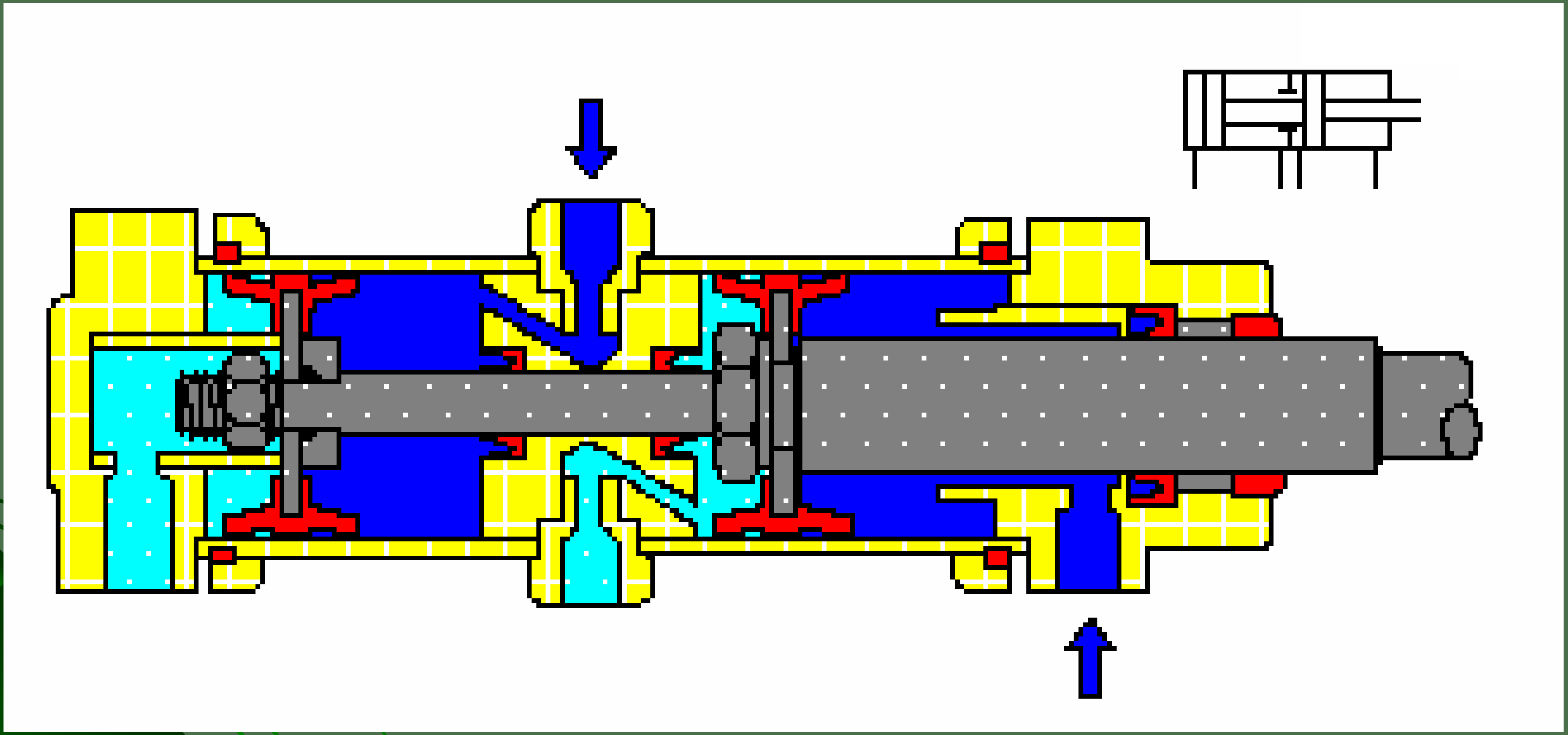
DOUBLE ACTING CYLINDERS



END POSITION CUSHIONING



TANDEM CYLINDER

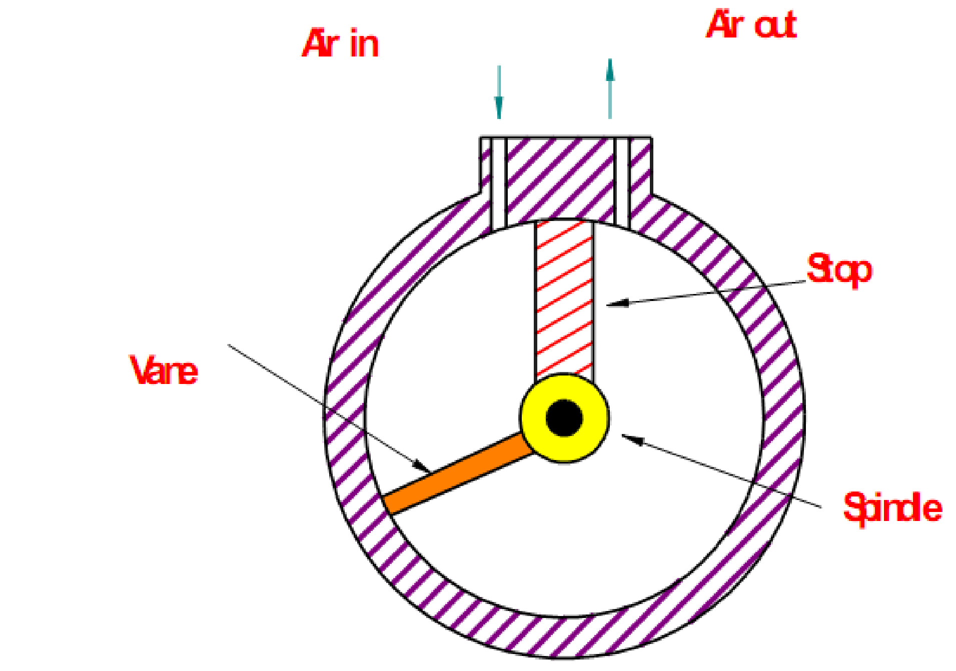


ROTARY ACTUATORS

In order to achieve angular motion, Rotary Actuators are used. Rotary actuators are mainly available in two designs.

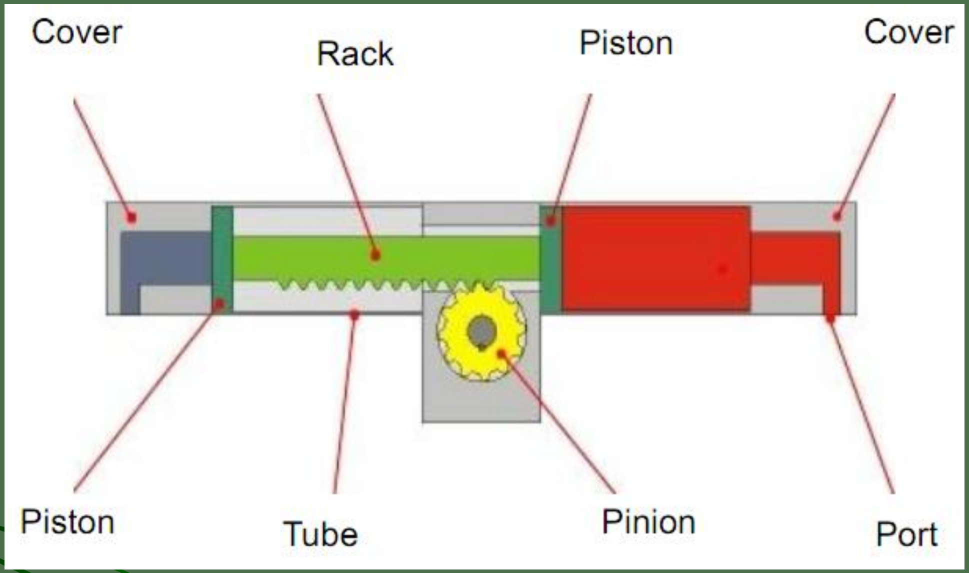
- Vane type Construction: Further these actuators are available with 180^0 rotation or 270^0 angle of rotation. These actuators can be used for low torque requirement up to 10 N-m.
- Rack and Pinion type construction: Can be used for angle or rotation close to 360^0. These actuators can develop torques up to 100-150 N-m depending on the diameter of the cylinder

VANE TYPE ROTARY ACTUATOR



•*A rotating vane connected to a shaft divides cylindrical chamber in to two compartments. Compressed air is alternately admitted and exhausted from the chambers. The compressed*

ROTARY ACTUATOR OF RACK AND PINION TYPE



This is essentially a double acting cylinder with a rack arrangement provided on the piston rod and a pinion engages with this rack. Out put rotation of the pinion shaft can

PART - B

UNIT – 7

DIRECTION CONTROL VALVES

DIRECTION CONTROL VALVES

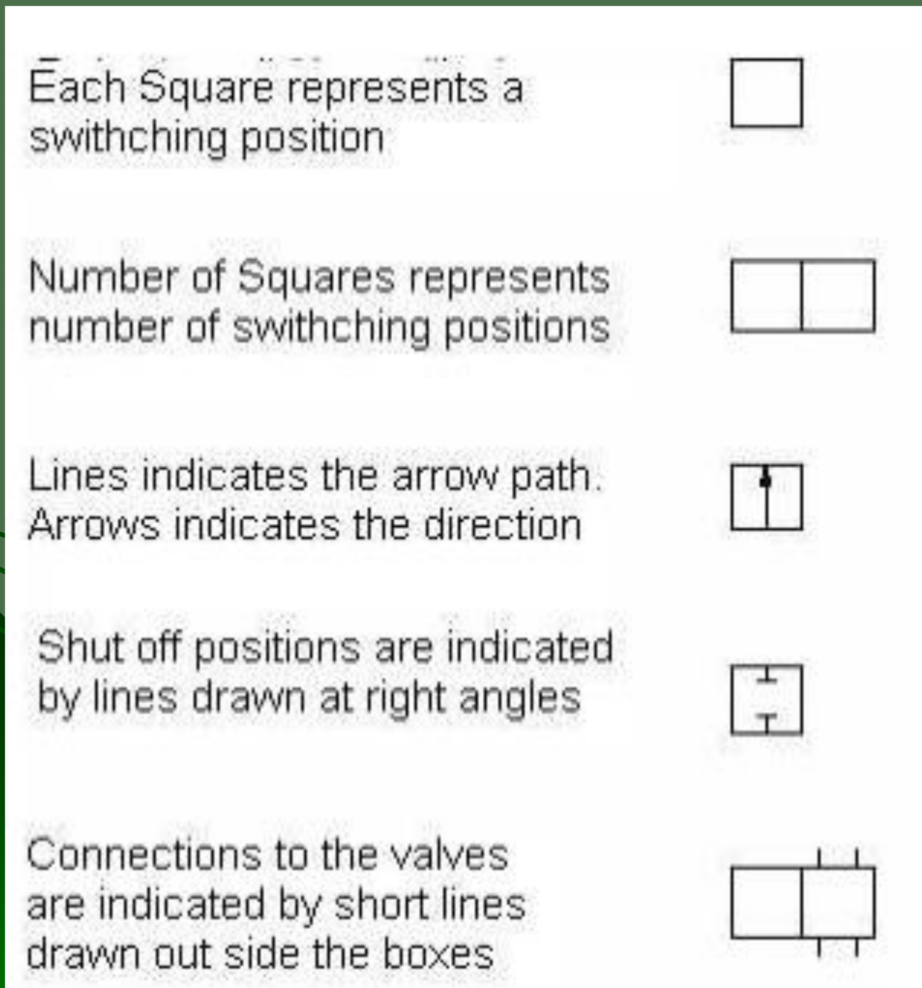
- Direction control valves are mainly used to change the direction of flow path of working medium or signal medium. They are used for admitting or exhausting working medium to the cylinder or from the cylinder for actuation of the cylinder.

DIRECTION CONTROL VALVES

- Direction control valves are designated as per the following functions.

  - Number of ports on the valves
  - Number of switching positions
  - Method of actuation
  - Method of reset
  - Design and constructional features

Symbolic Representation of Directional Control Valves



Each Square represents a swithching position

Number of Squares represents number of swithching positions

Lines indicates the arrow path. Arrows indicates the direction

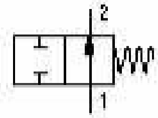
Shut off positions are indicated by lines drawn at right angles

Connections to the valves are indicated by short lines drawn out side the boxes

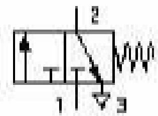
Symbolic Representation of Directional Control Valves

Number of ports
Number of positions

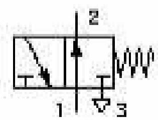
2/2 Way Directional Control Valves Normally Open



3/2 Way Directional Control Valves Normally Closed

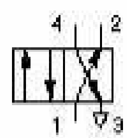


3/2 Way Directional Control Valves Normally Open

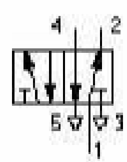


Number of ports
Number of positions

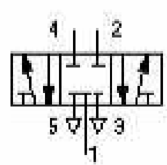
4/2 Way Valve



5/2 Way Valve



5/3 Way Valve ,
Mid Position Closed



Symbolic Representation of Directional Control Valves

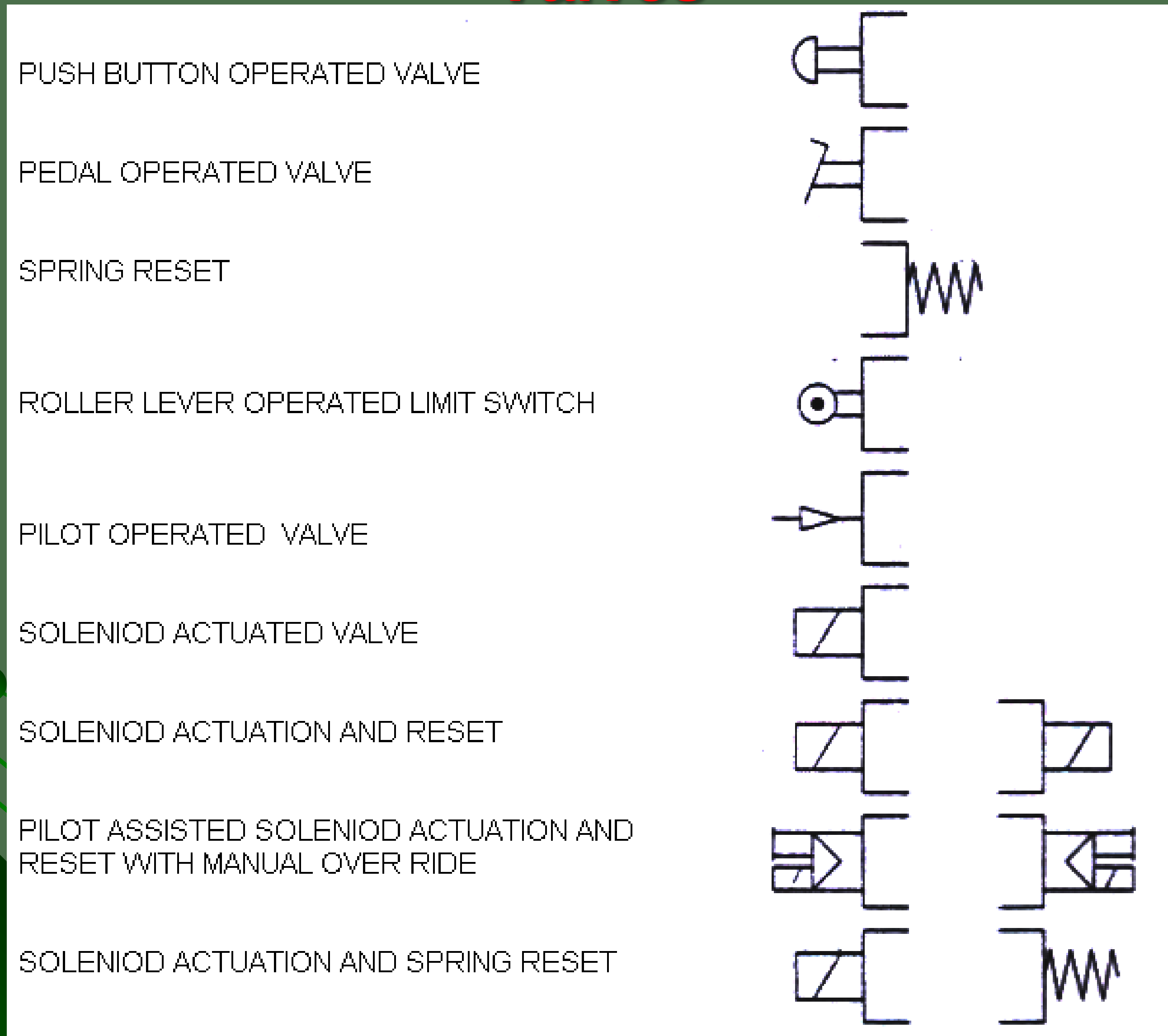
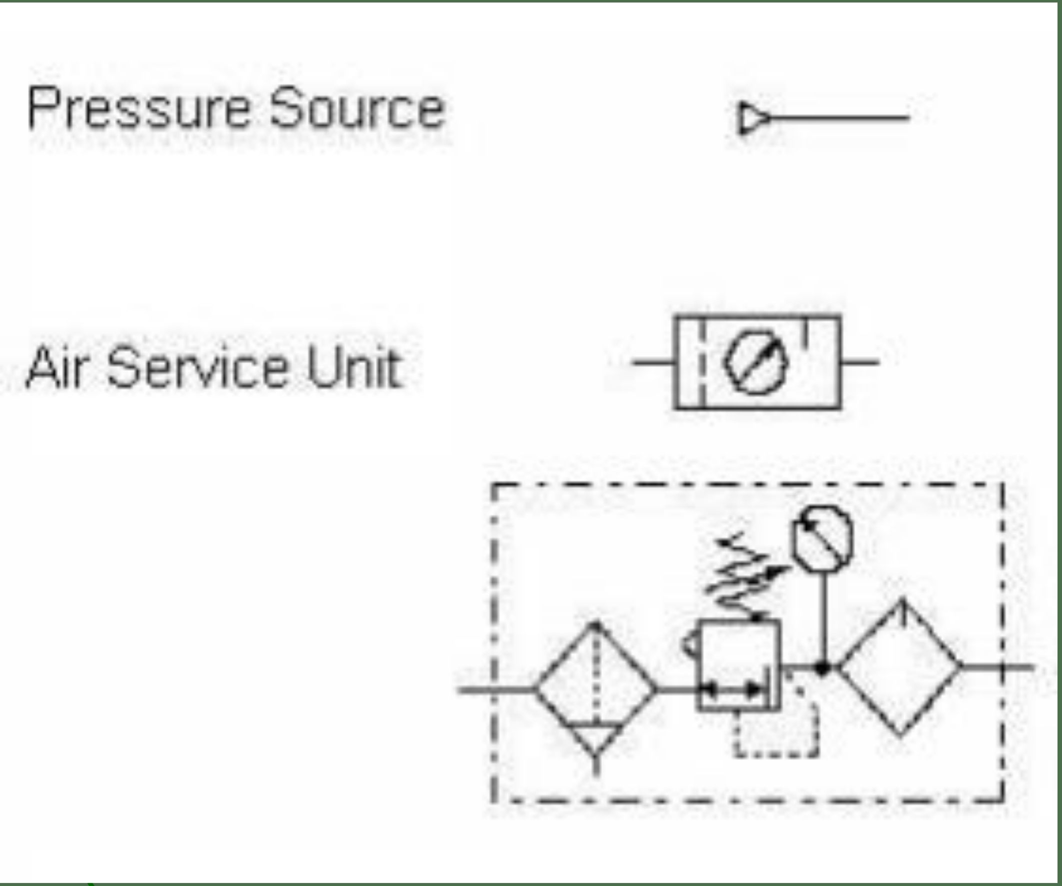


Fig. Method of Actuation and Reset

Symbolic Representation of Directional Control Valves



Symbols for Energy Elements

Port marking of direction control valve

As per IS 1219		As per IS 5599	
•Supply Port	A	Supply Port	1
•Exhaust Ports	R & S	Exhaust Ports	3 & 5
•Out put Pots	A & B	Out put Ports	2 & 4
•Pilot Port [Set]	Z	Pilot Port [Set]	14
•Pilot Port [Reset]	Y	Pilot Port [Reset]	12

Design and construction features of DC valve

- Poppet type of valves

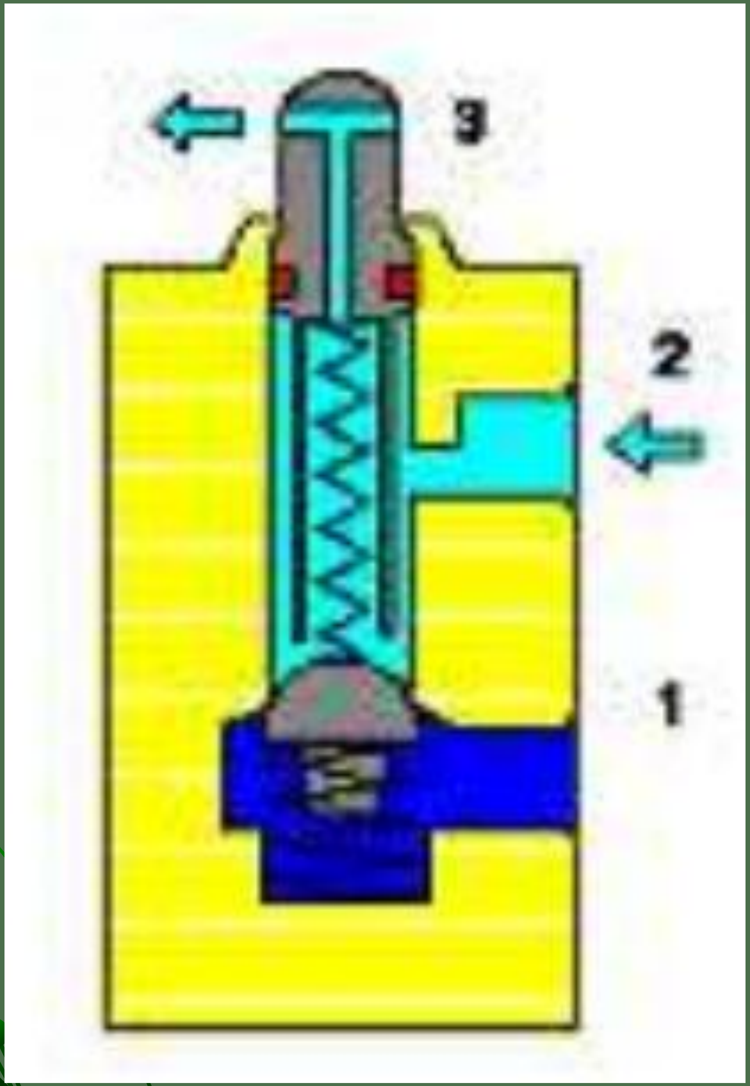
  Ball seat type (Pneumatic/Solenoid actuation)

  Disc seat type (Pneumatic/Solenoid actuation)
- Slid valves (Pneumatic/Solenoid actuation)
- Suspended disc type of valve (Pneumatic/Solenoid actuation)
- Plate of valve (manual actuation)

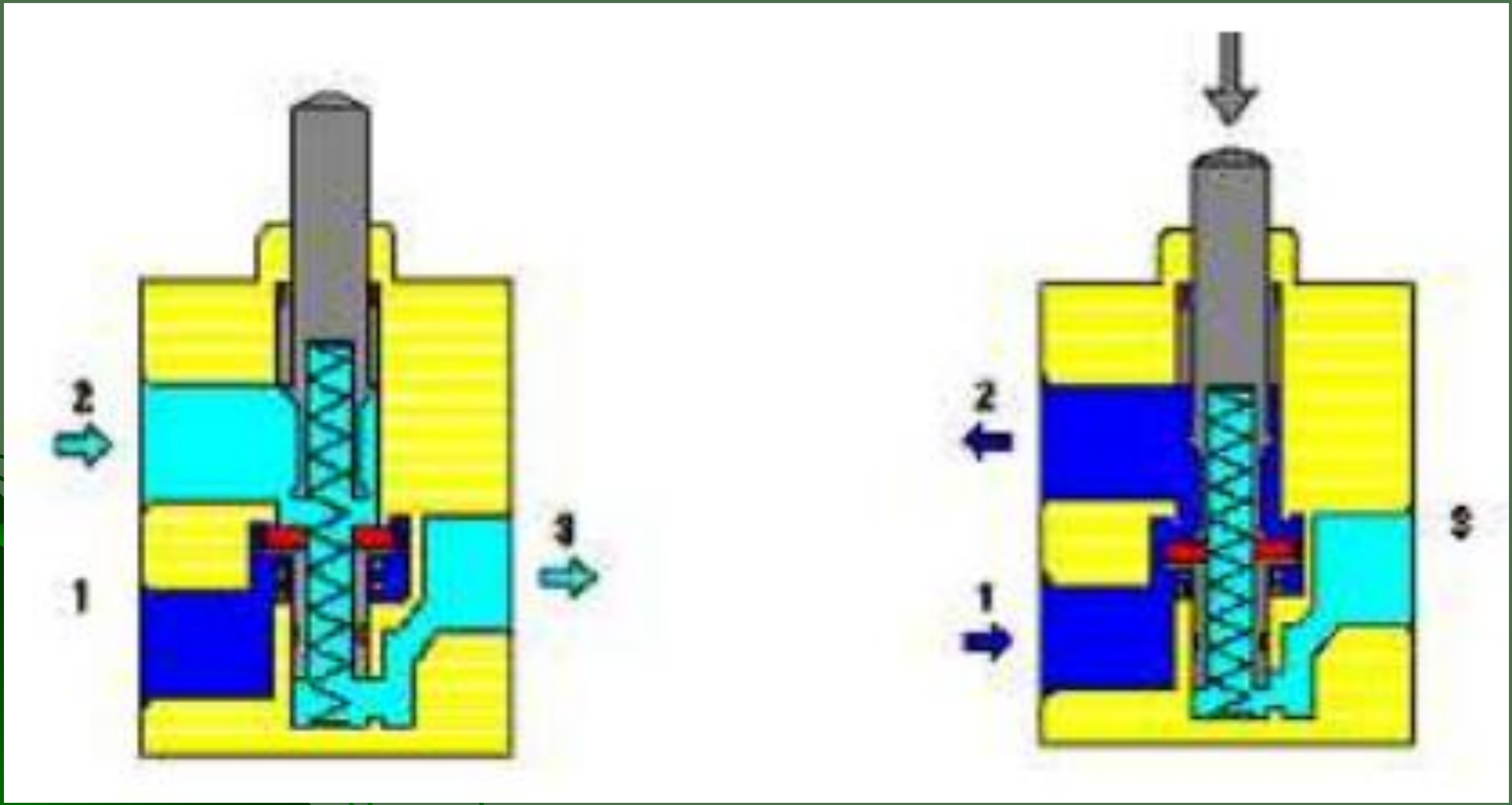
Selection criteria of D.C valve

- Actuation force
- Leak tightness
- Ease of servicing
- Sensitive to contamination by dirt
- Travel length of valve stem
- Size
- Cost

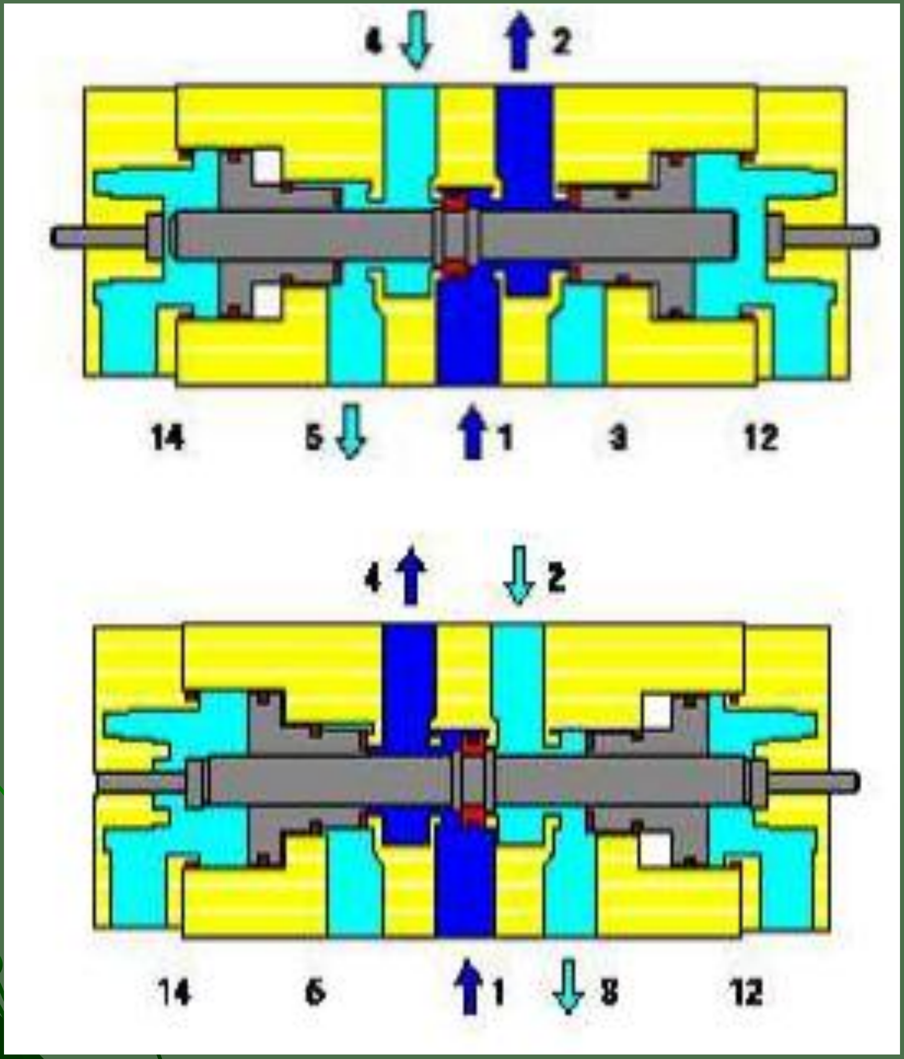
3/2 way ball seat type D.C valve



3/2 way disc seat valve (normally closed)



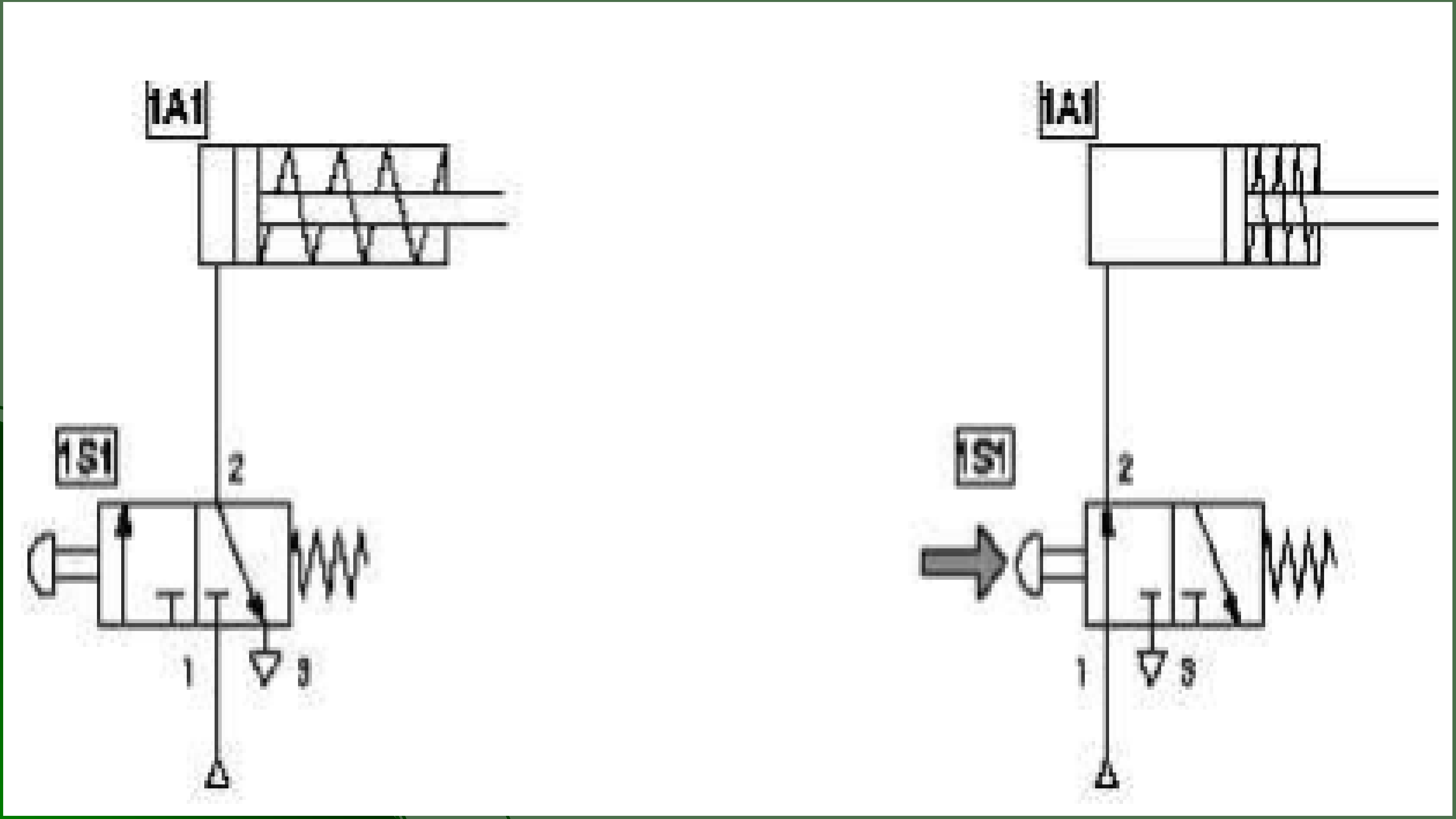
5/2 way suspended disc seat type valve (normally closed)



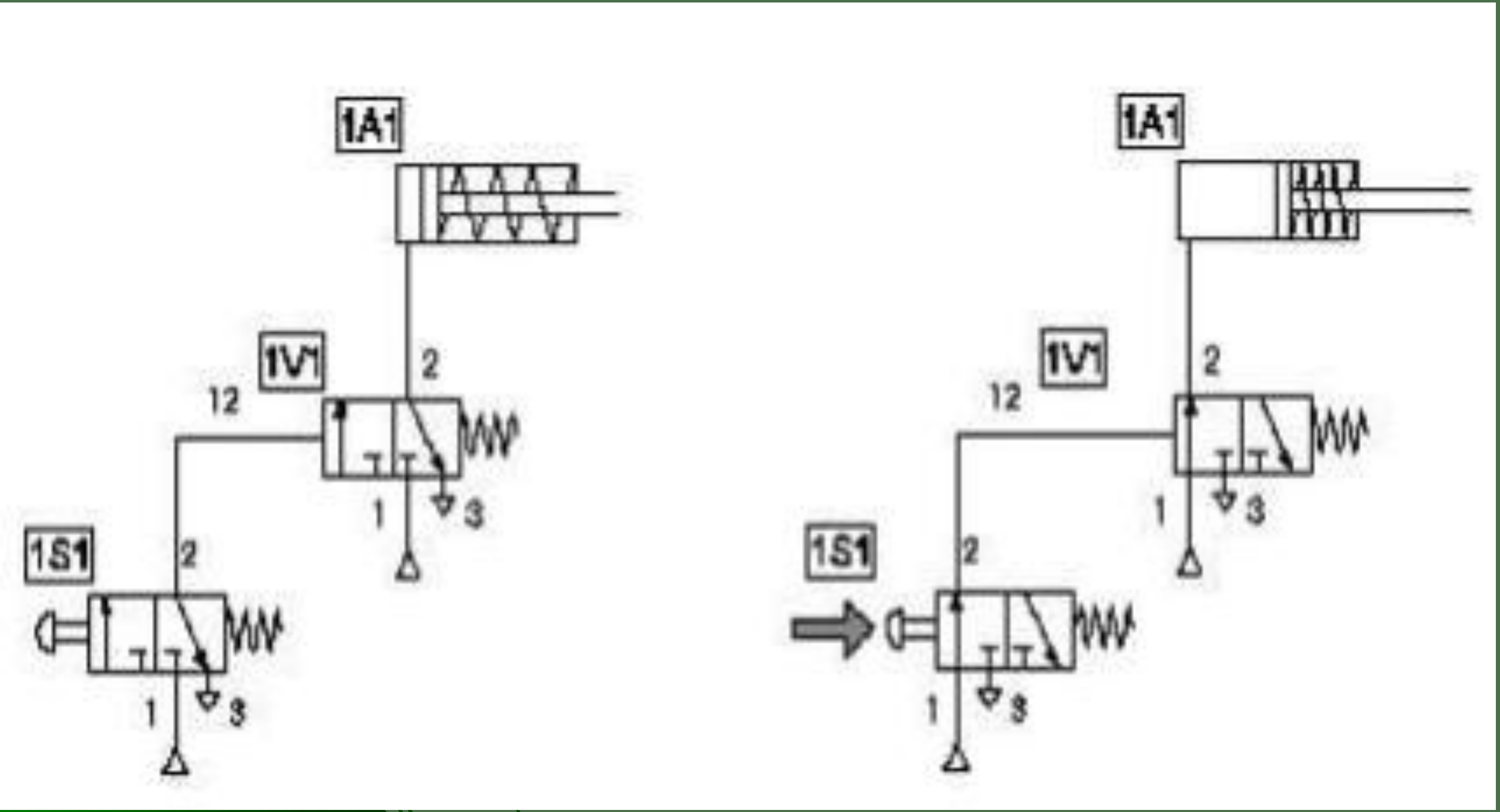
Controlling of pneumatic cylinders

- Pneumatic cylinders can be controlled by following methods.
  - Direct control of single or double acting cylinder
  - Indirect control of cylinder with single pilot control valve
  - Indirect control of cylinder with double piloted control valve

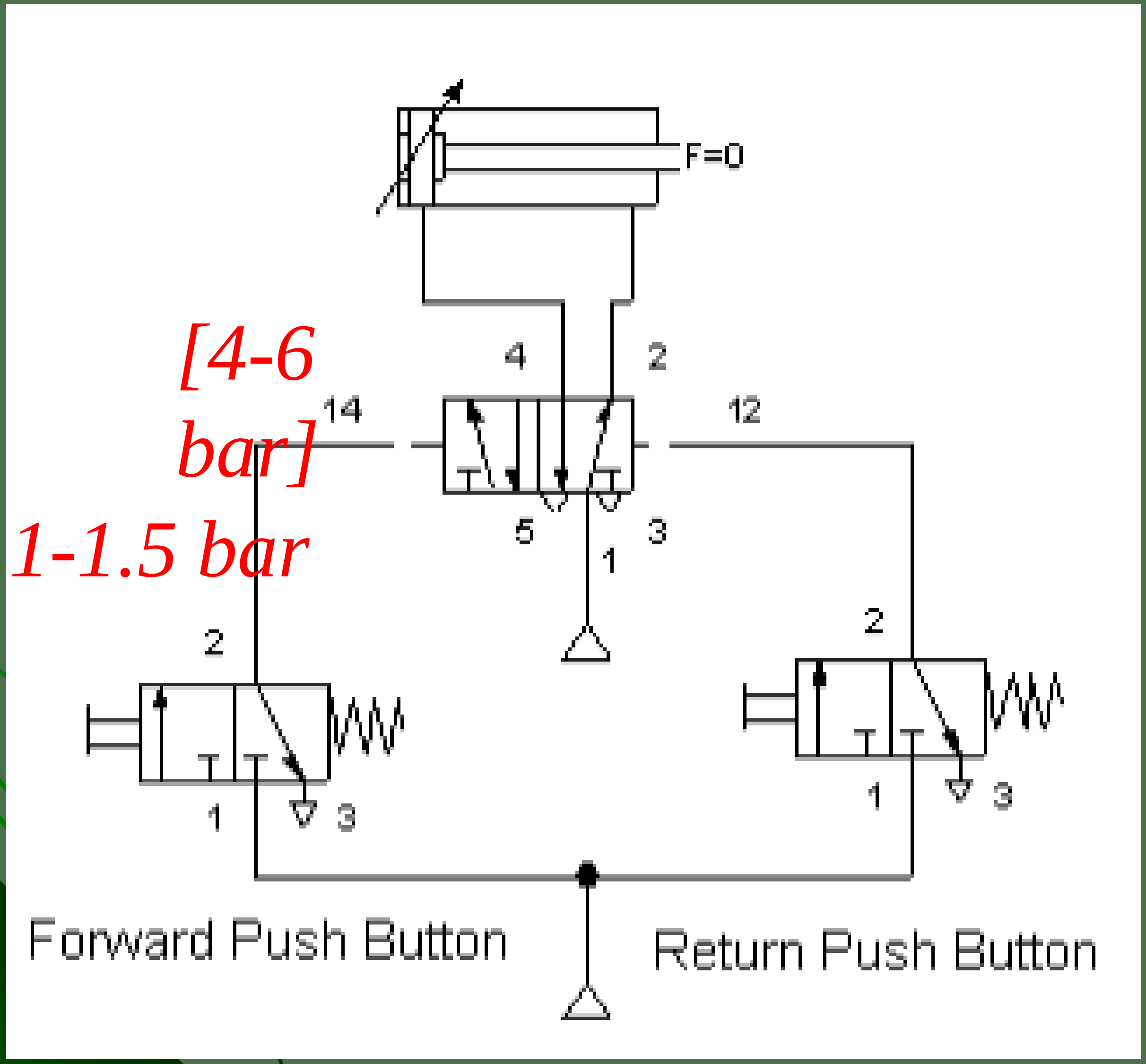
Direct control of single acting cylinder



Indirect control of single acting cylinder with single piloted final control valve



Indirect control of cylinder with double piloted final control valve

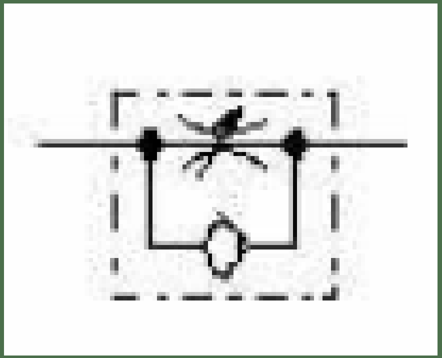


Speed control of cylinders

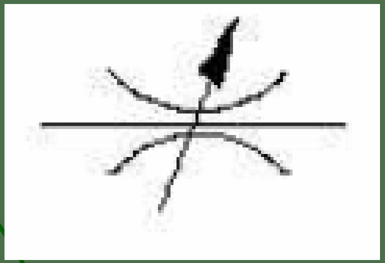
- It is always necessary to reduce the speed of cylinder from maximum speed based on application.
- Speed control of pneumatic cylinder can be conveniently achieved by regulating the flow rate supply or exhaust air.
- The volume flow rate of air can be controlled by using flow control valves which can be either two way or one way flow control valve.

Flow control valves

- One way flow control valve

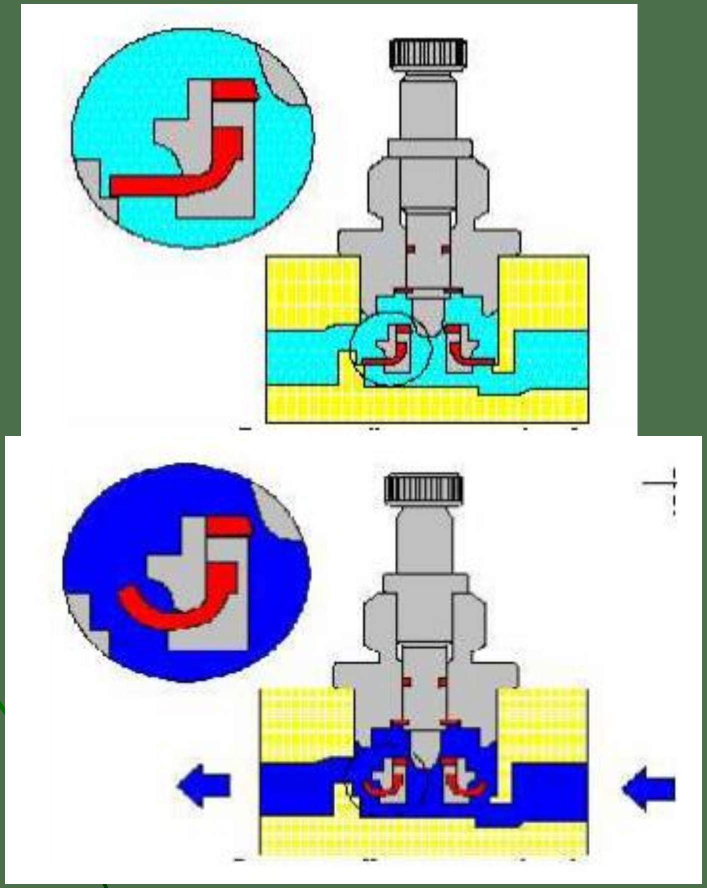


- Two way flow control valve

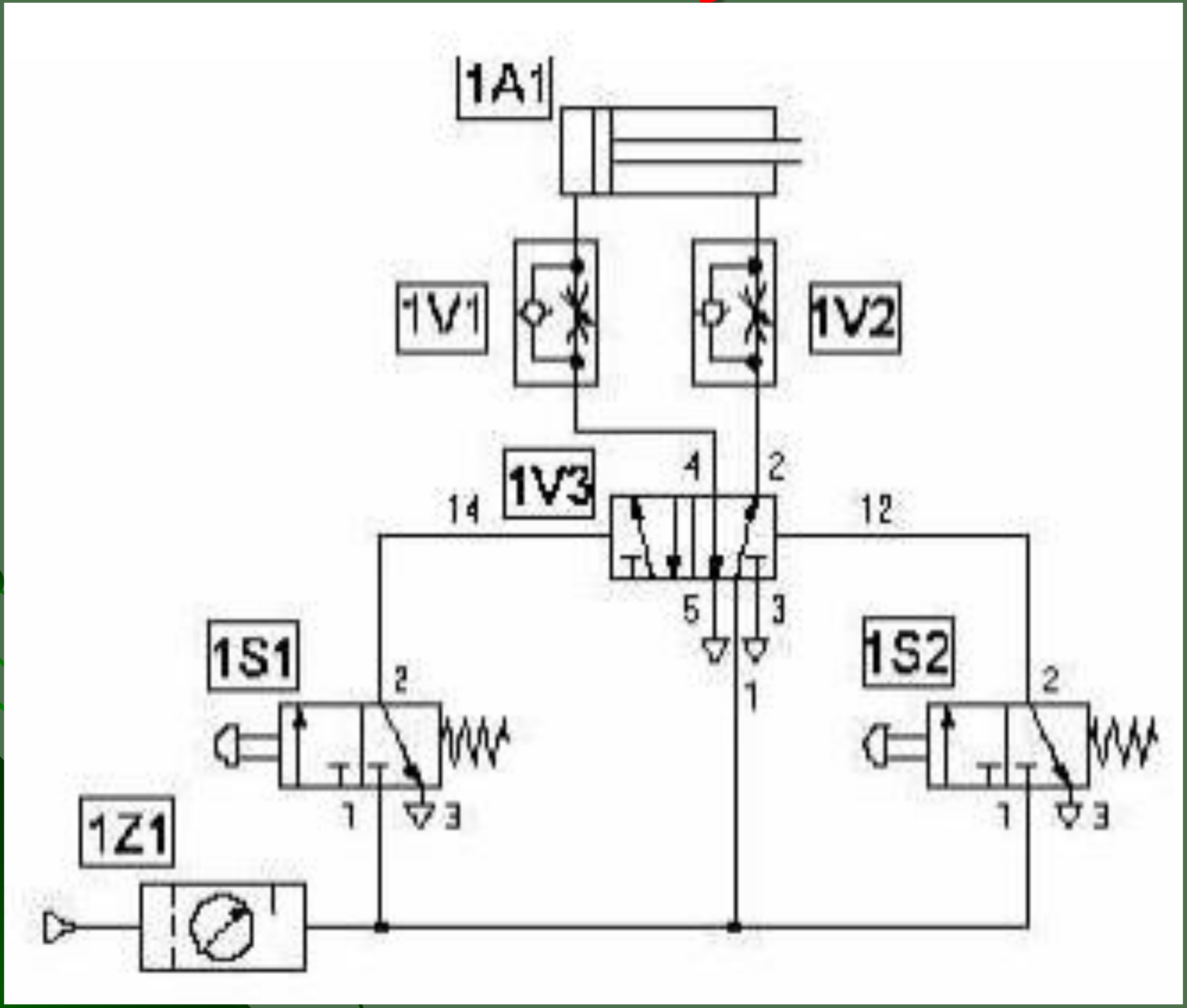


One way flow control valve

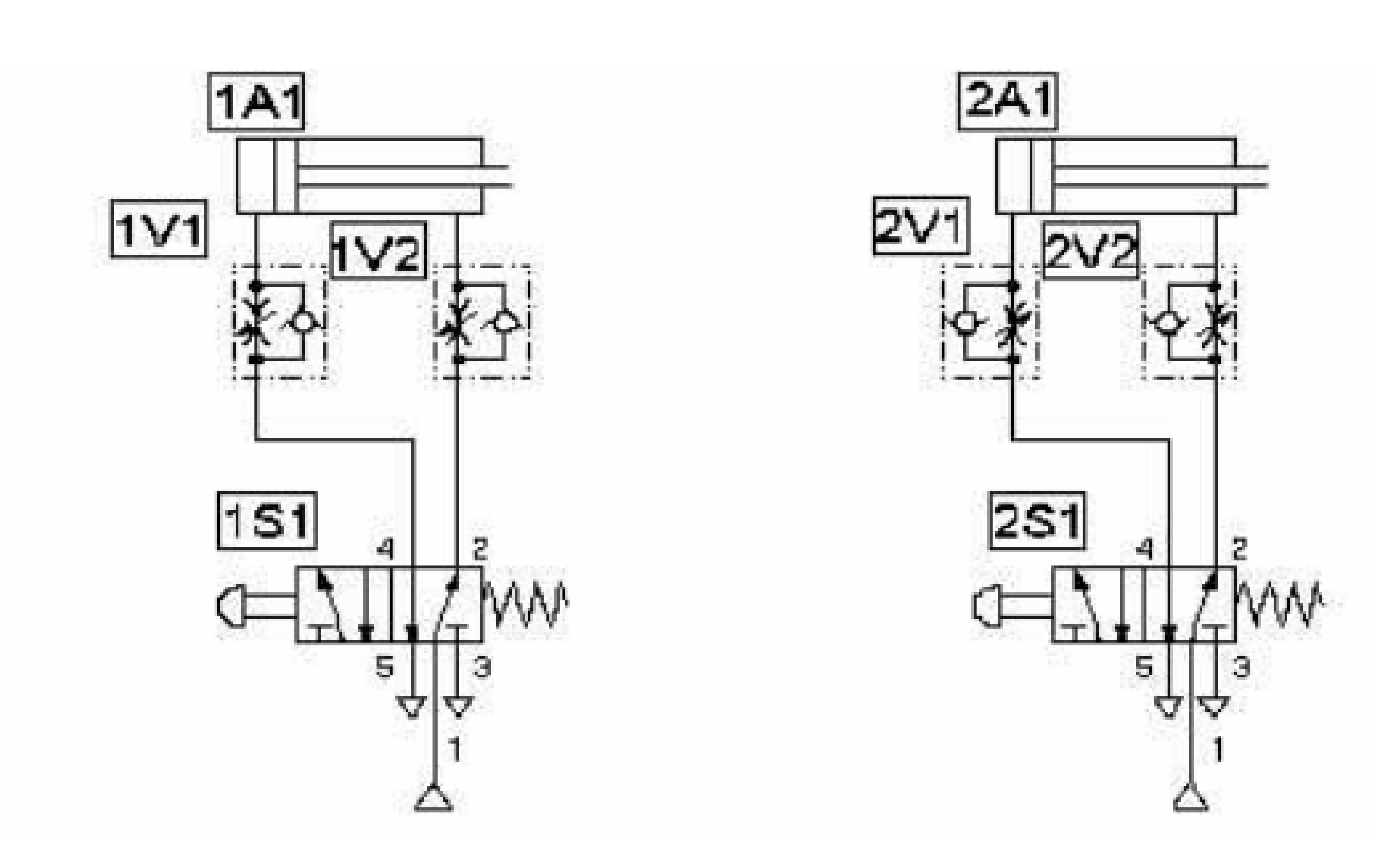
- It is also called as throttle relief valve



Use of flow control valve for speed control of cylinder



Use of flow control valve for speed control of cylinder



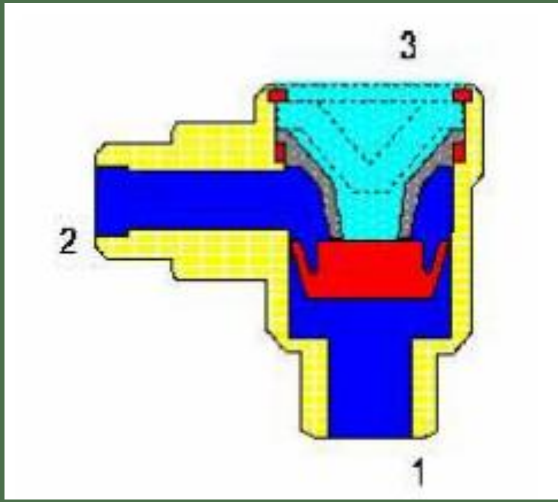
Slip stick effect

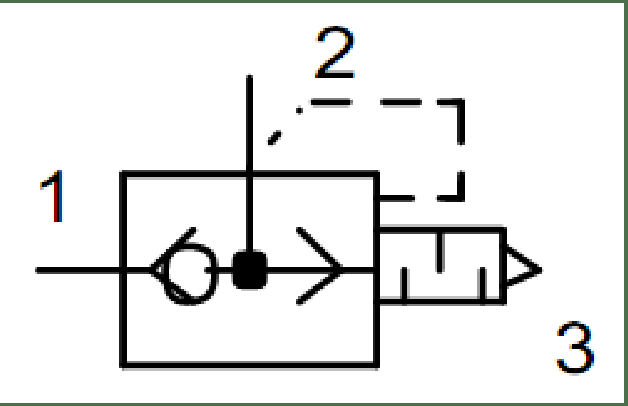
There is a limitation is achieving smooth movement of cylinder with low speed setting of flow control valve. This results in jerky motion of piston which is called as the stick slip effect

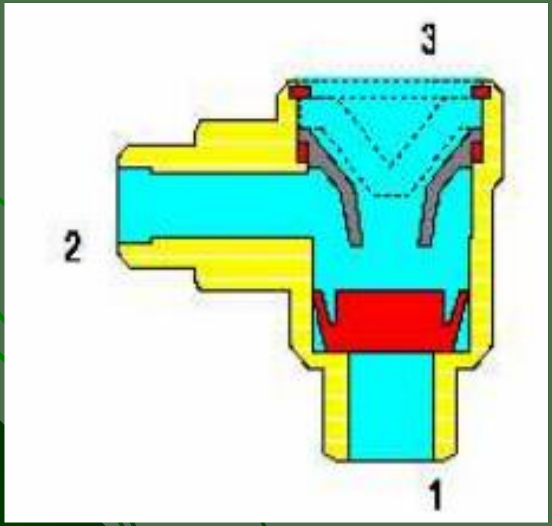
When the flow control valve is set for low flow rates, it takes considerable time for the supply air to build up to the required pressure [corresponding to the load]

behind the piston. Every time this pressure is reached, the piston jerks in the direction of motion which results in increase in cylinder volume. This further results in drop in pressure in the cylinder and the piston momentarily halts until the pressure build up takes place. This intermittent motion is called as the Stick Slip Effect

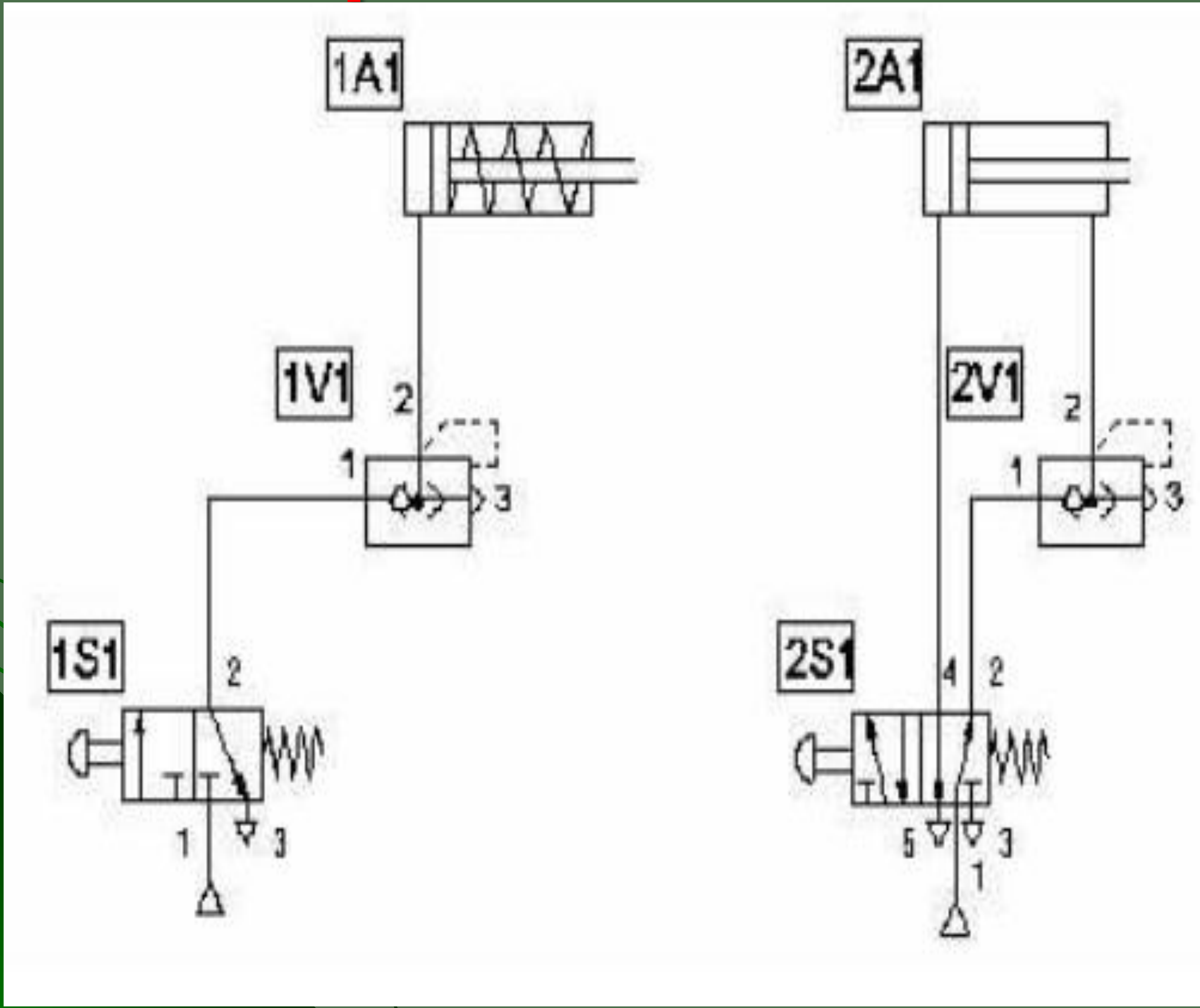
Quick exhaust valve





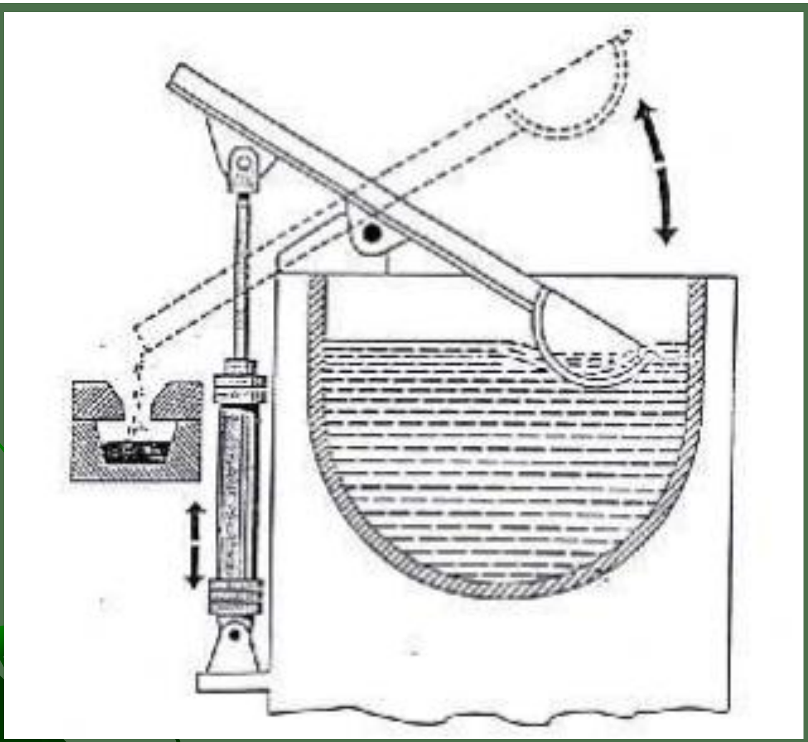


Use of quick exhaust valve

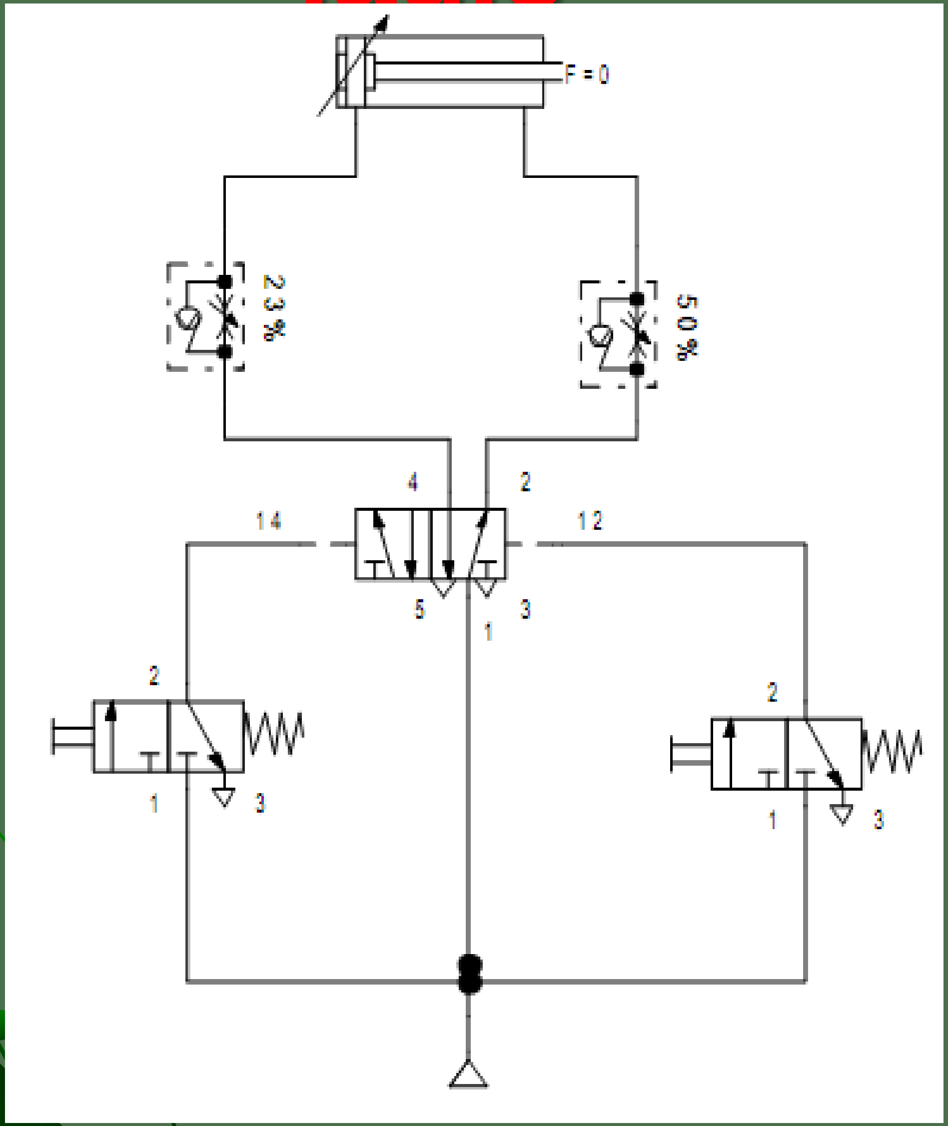


Exercise

Liquid metal is drawn from a smelting crucible by a casting ladle and cast in moulds. The raising and lowering of the ladle is controlled by separate manual push buttons. The raising and lowering speed is separately adjustable . Design a Pneumatic control circuit for this application



Pneumatic control for casting ladle

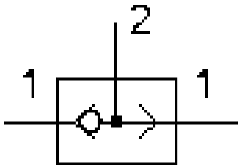


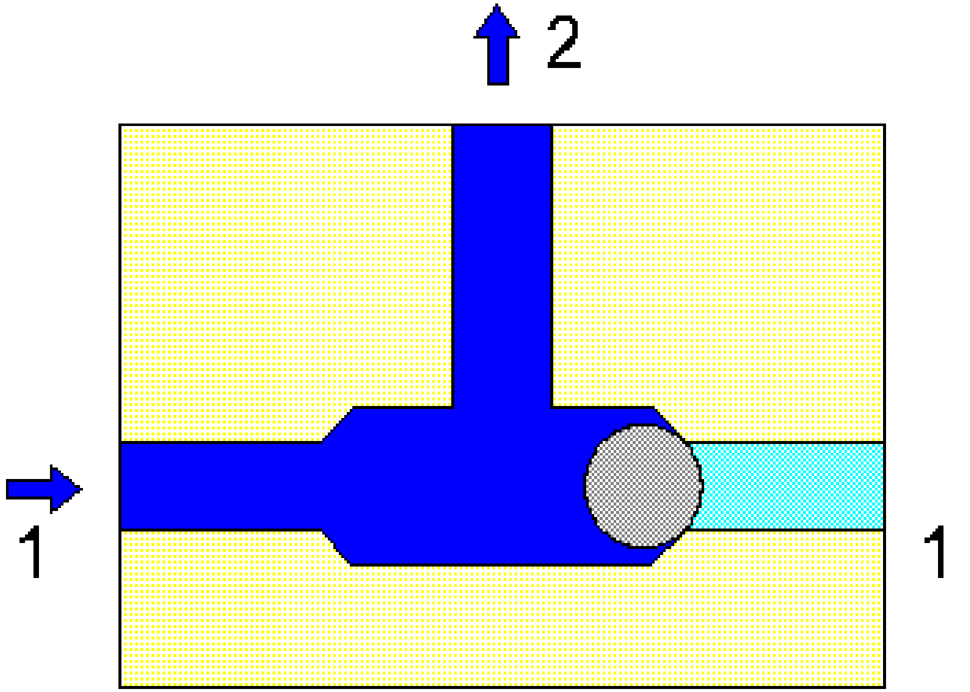
Signal processing elements

- To meet the requirements of various conditions in pneumatic applications, signal processing devices are often used. The following gates or valves are used depending on required c

- OR Gate – Shuttle Valve – Used to select one of the two input signals
- AND Gate- Two Pressure Valve- To combine two input signals i.e to satisfy two conditions at the same time
- NOT Gate- 3/2 way, normally open, pilot operated Directional Control Valve- Used to negate the function

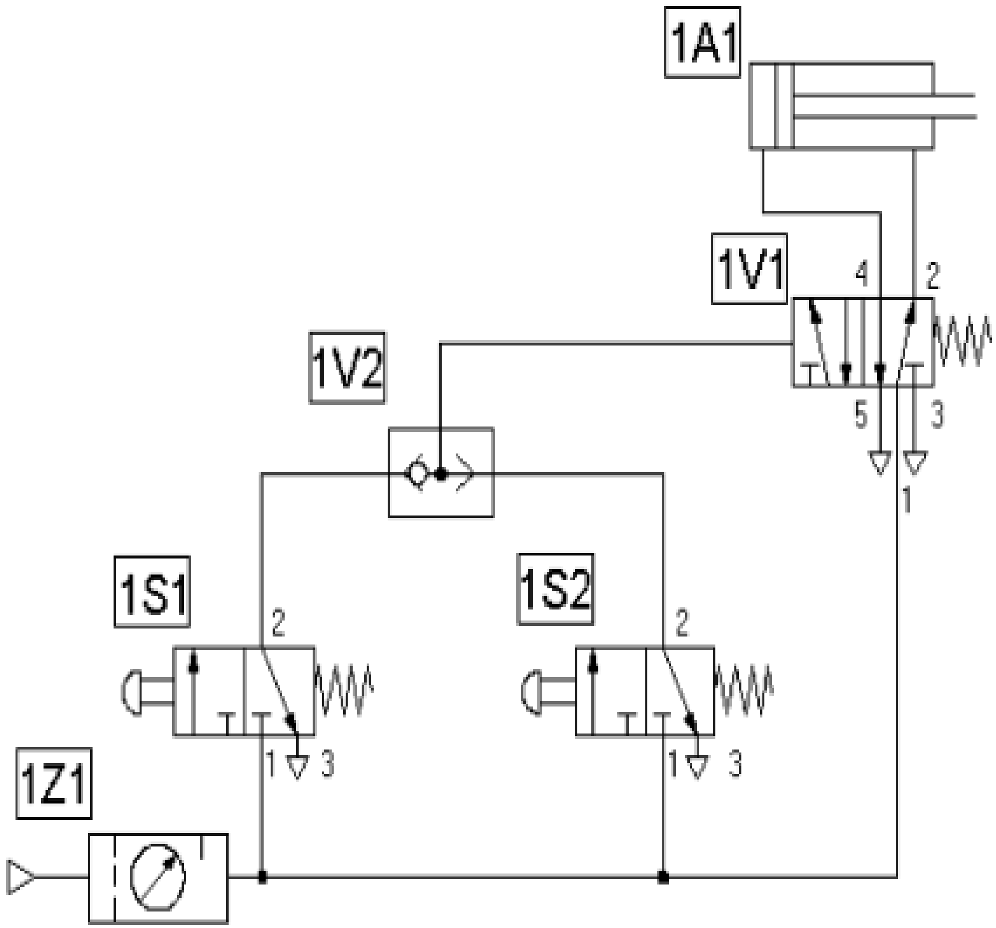
Shuttle Valve as OR Gate





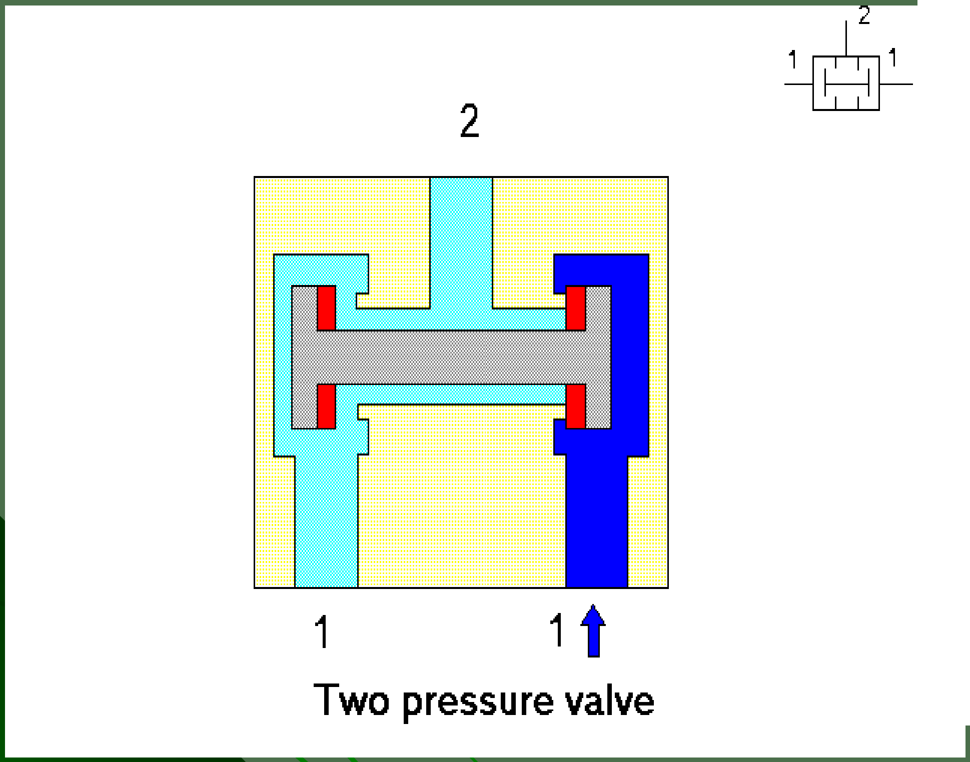
Shuttle valve

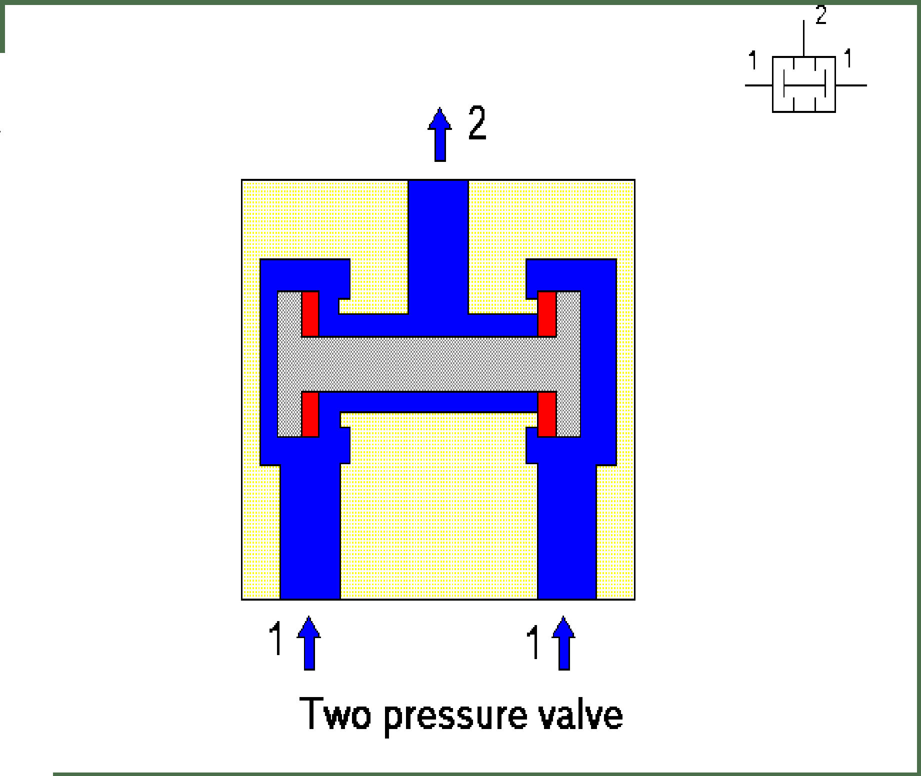
Shuttle valve as OR Gate



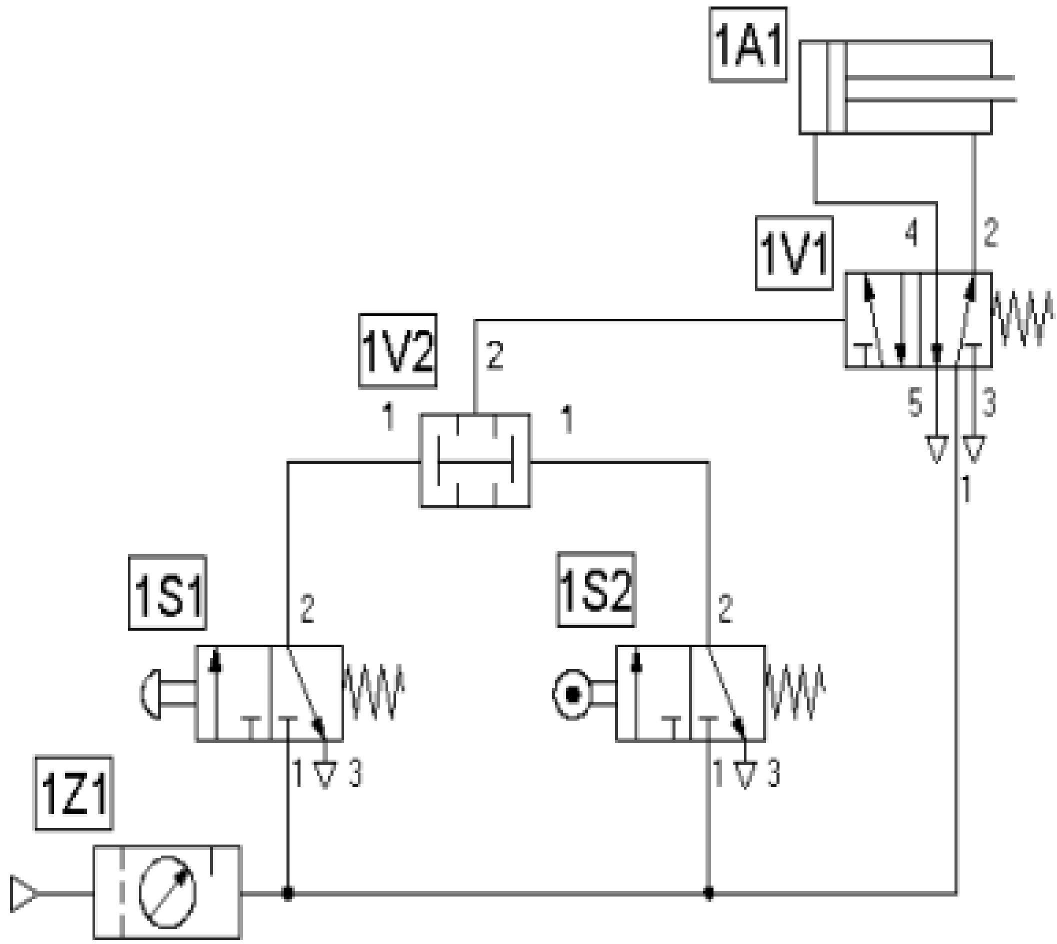
Circuit diagram: Shuttle valve

Twin pressure valve as AND Gate





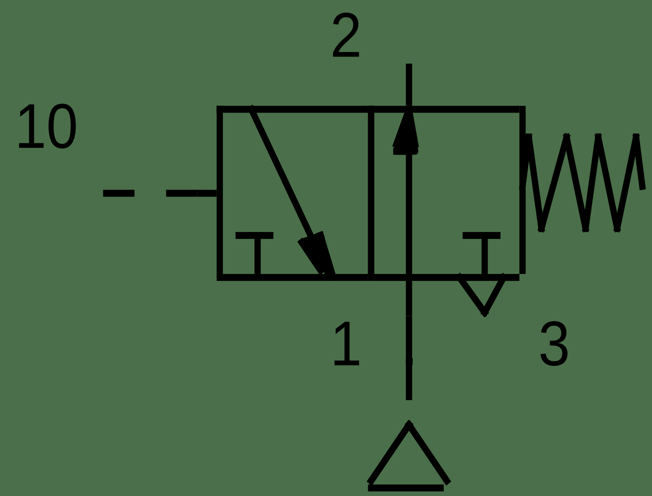
Twin pressure valve as AND Gate



Two pressure valve

Not Gate

.



Not Gate is generally used to invert the signal status i. e to negate the signal. For example a normally closed timer or counter can be converted to normally open and vice versa. It is essentially a normally open 3/2 way, pilot operated directional control valve Input signal is applied at pilot port 10 and out put is taken from port 2.

Pressure and time dependent valves

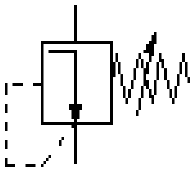
- **Pressure Dependent Valves**

- The following Pressure Dependent Controls are often used in Pneumatic applications

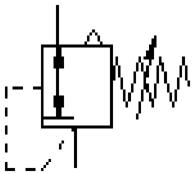
- Pressure Sequence Valve
- Pressure Relief Valve
- Pressure Regulator

Pressure Sequence Valves

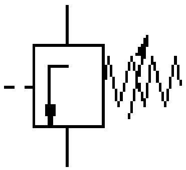
Adjustable pressure regulating valve
Non-relieving type



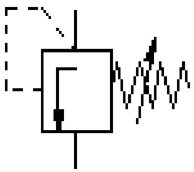
Adjustable pressure regulating valve
relieving type (overloads are vented)



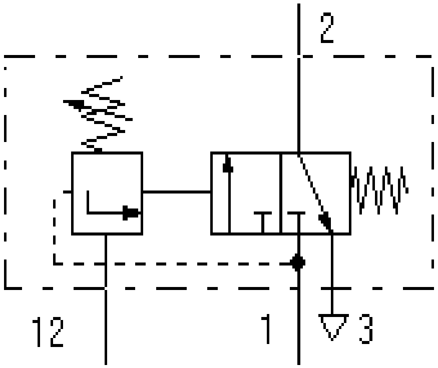
Sequence valve
external source



Sequence valve
in-line



Sequence valve
combination

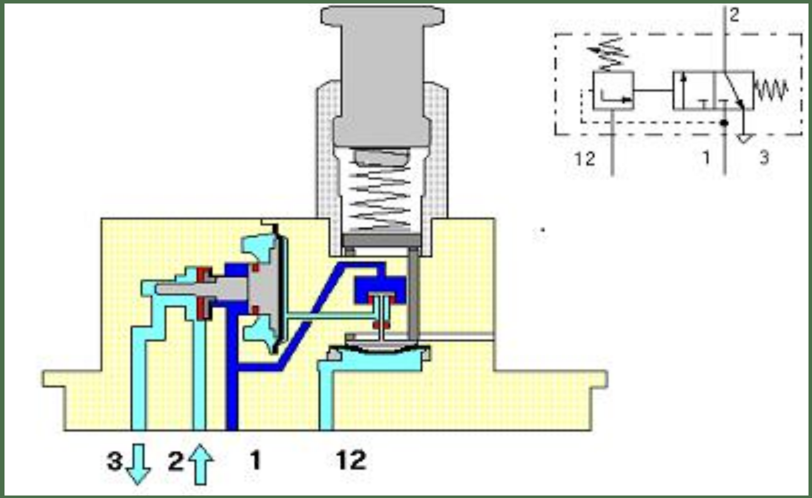


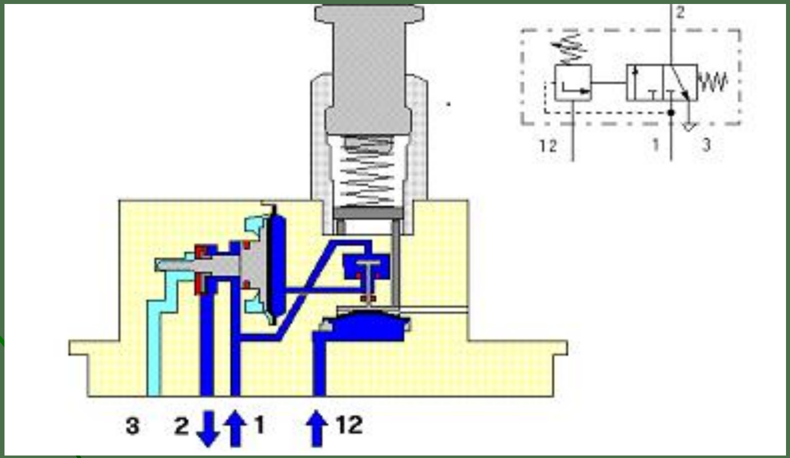
Pressure control valves

Pressure Sequence Valve

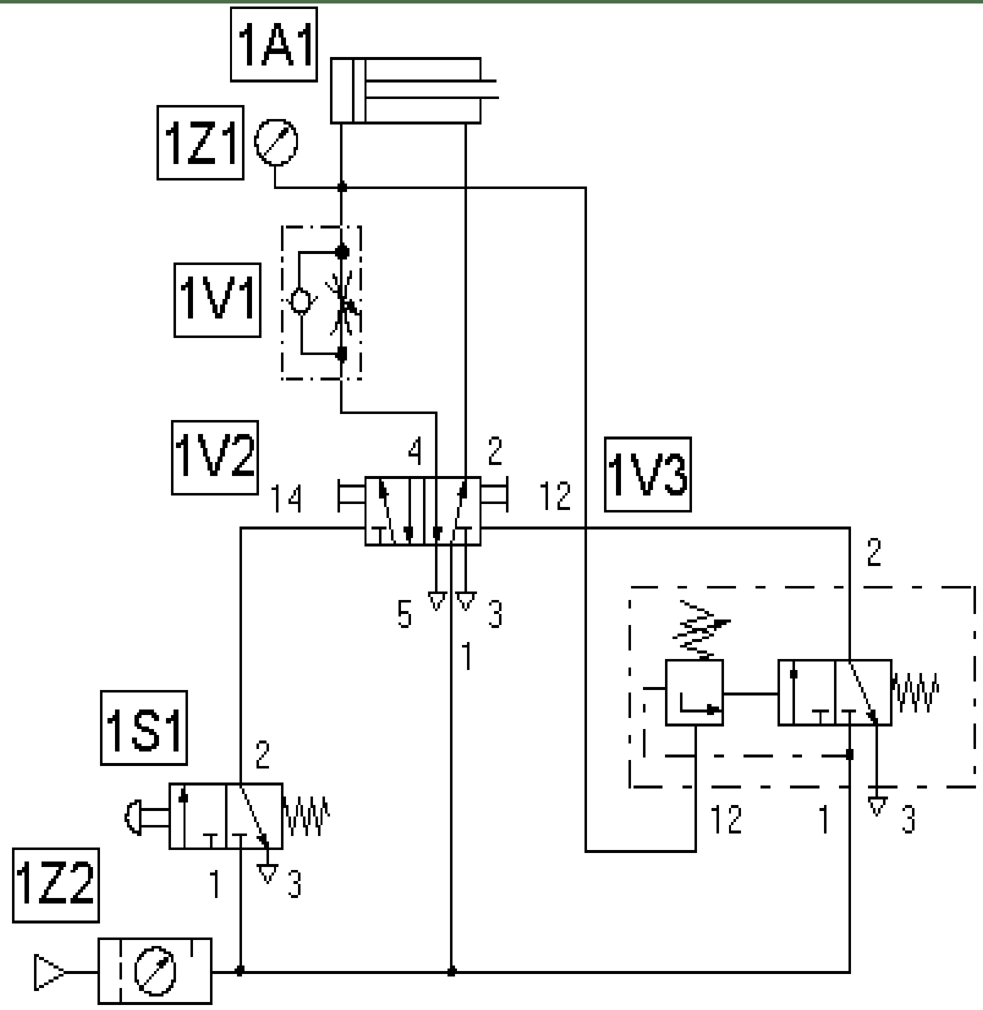
- Pressure Sequence valve is essentially a switch on or off valve
- Sequence Valve generates a pneumatic signal if the sensing pressure [signal input] is more than the desired set pressure
- This generated out put signal is used to control the movement of cylinder by using it as a set signal or reset signal to the final control valve to obtain forward or return motion respectively
- Used for applications such as bonding cylinders, clamping cylinder etc. to ensure desired minimum pressure in the cylinder
- This is a combination valve, having two sections. One of the section is a 3/2 directional control and the other a pressure control valve

Pressure Sequence Valve





Pressure sequence valve circuit

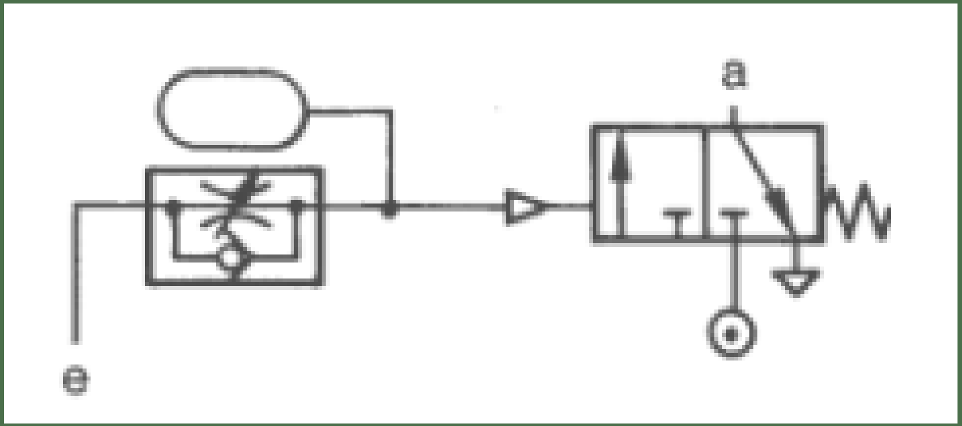


Pressure sequence valve circuit

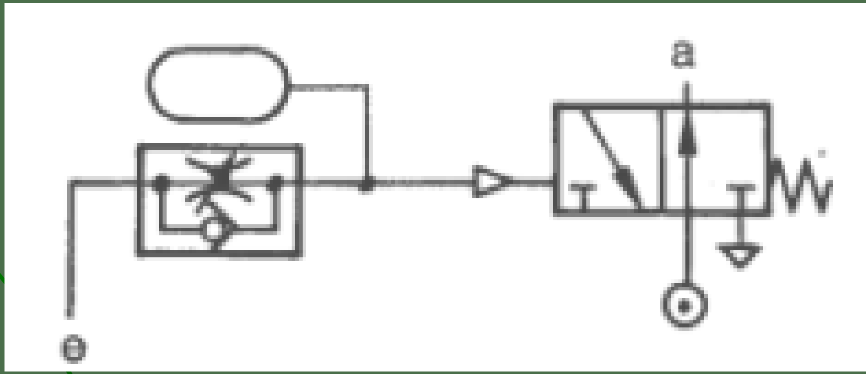
Pneumatic Timers

- Pneumatic Timers are used to create time delay of signals in pilot operated circuits.
- Available as Normally Closed Timers and Normally Open Timers.
- Usually Pneumatic timers are on Delay Timers
- Delay of signals is very commonly experienced in applications such as Bonding of two pieces.
- Normally Open Pneumatic Timer are also used in signal elimination
- Normally Open Pneumatic Timers are used as safety device in   Two Hand Blocks

Types of pneumatic timers

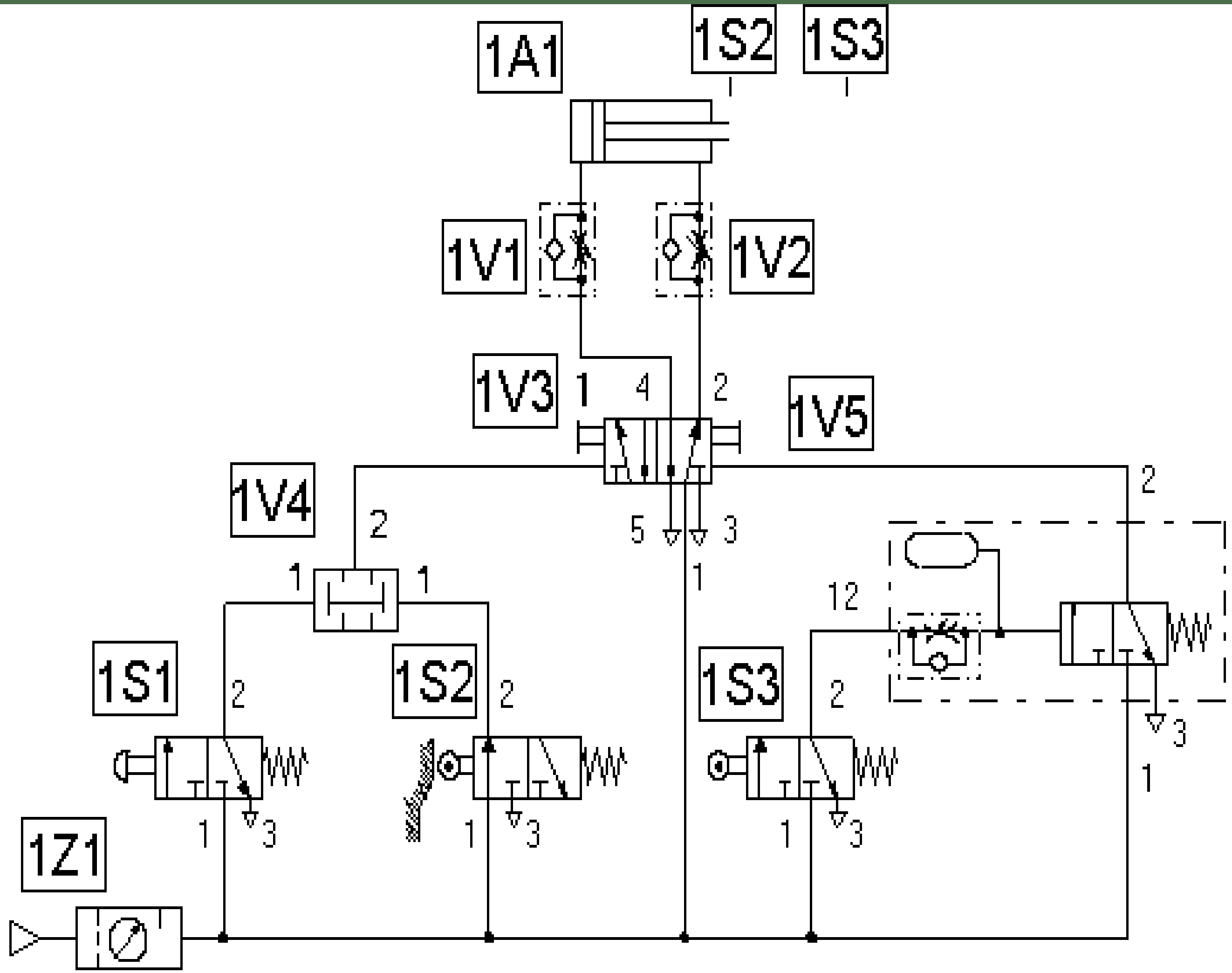


Normally opened or ON delay timer



Normally closed or OFF delay timer

Time delay valve circuit



Time delay valve circuit

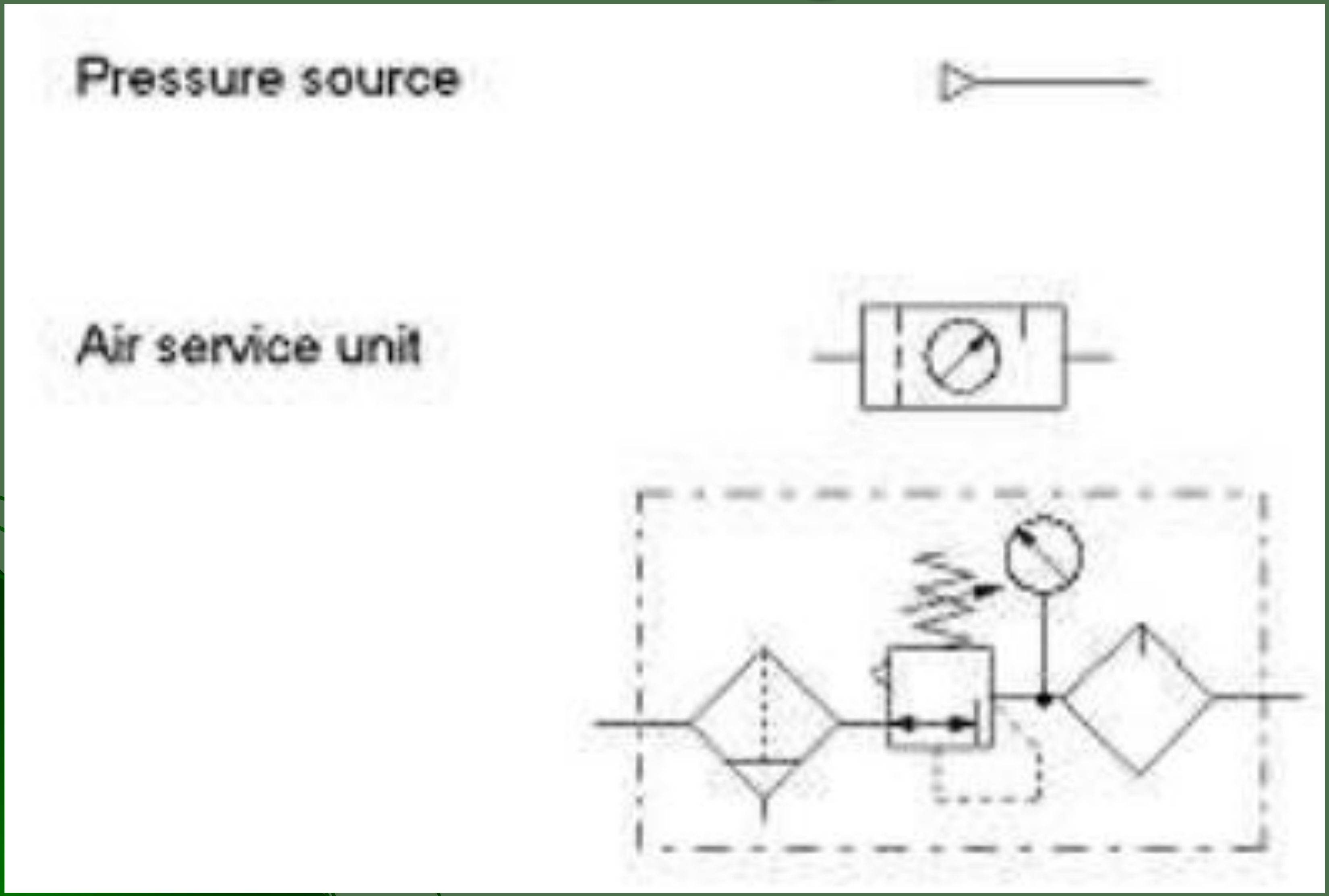
UNIT – 8

MULTI – CYLINDER APPLICATIONS

Compressed air production, preparation and distribution

- ENERGY ELEMENTS
- Air Compressor and Accessories
- Air Preparation
- Air Regulation
- Air Lubrication

Air Servicing Unit

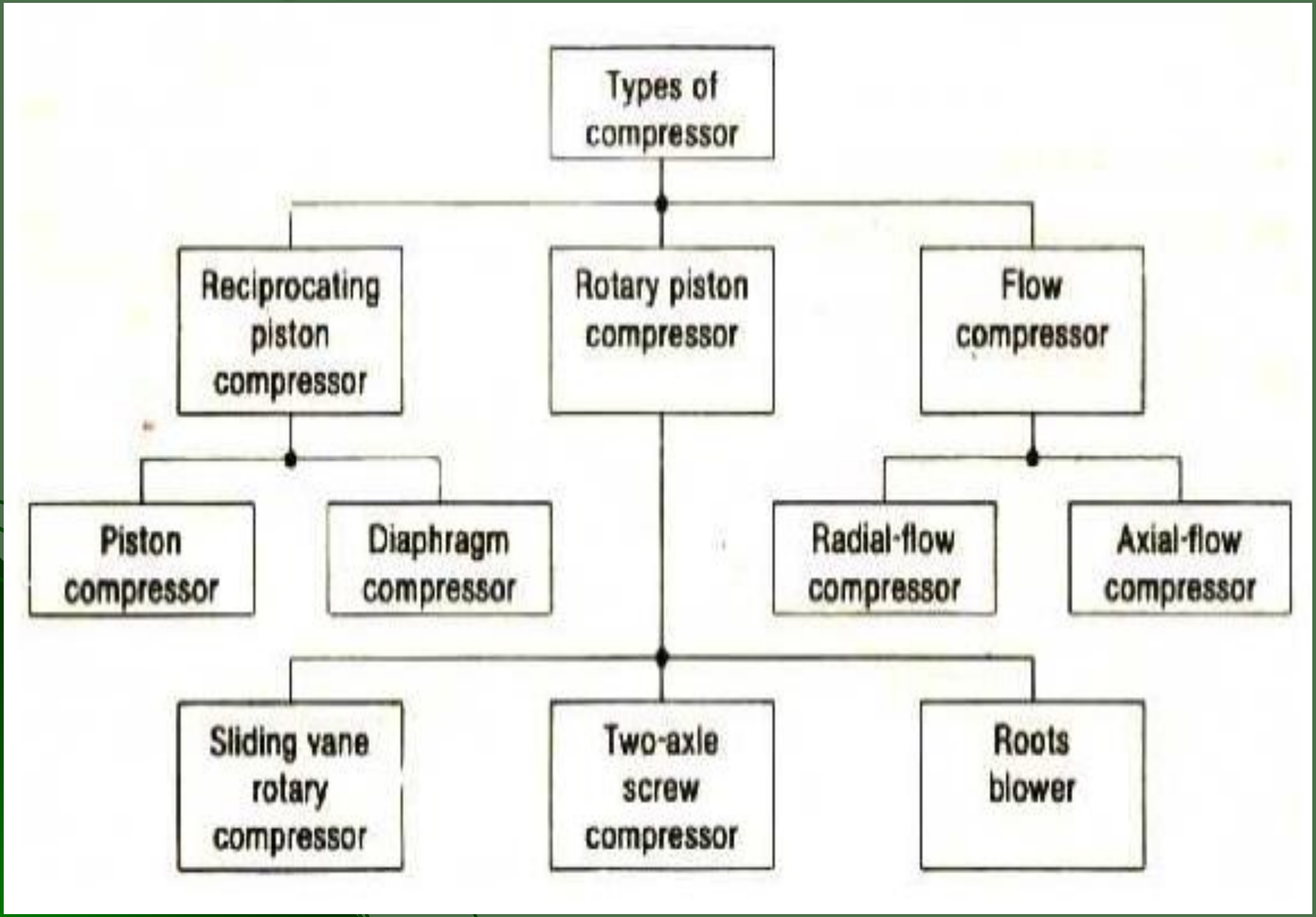


Air compressors

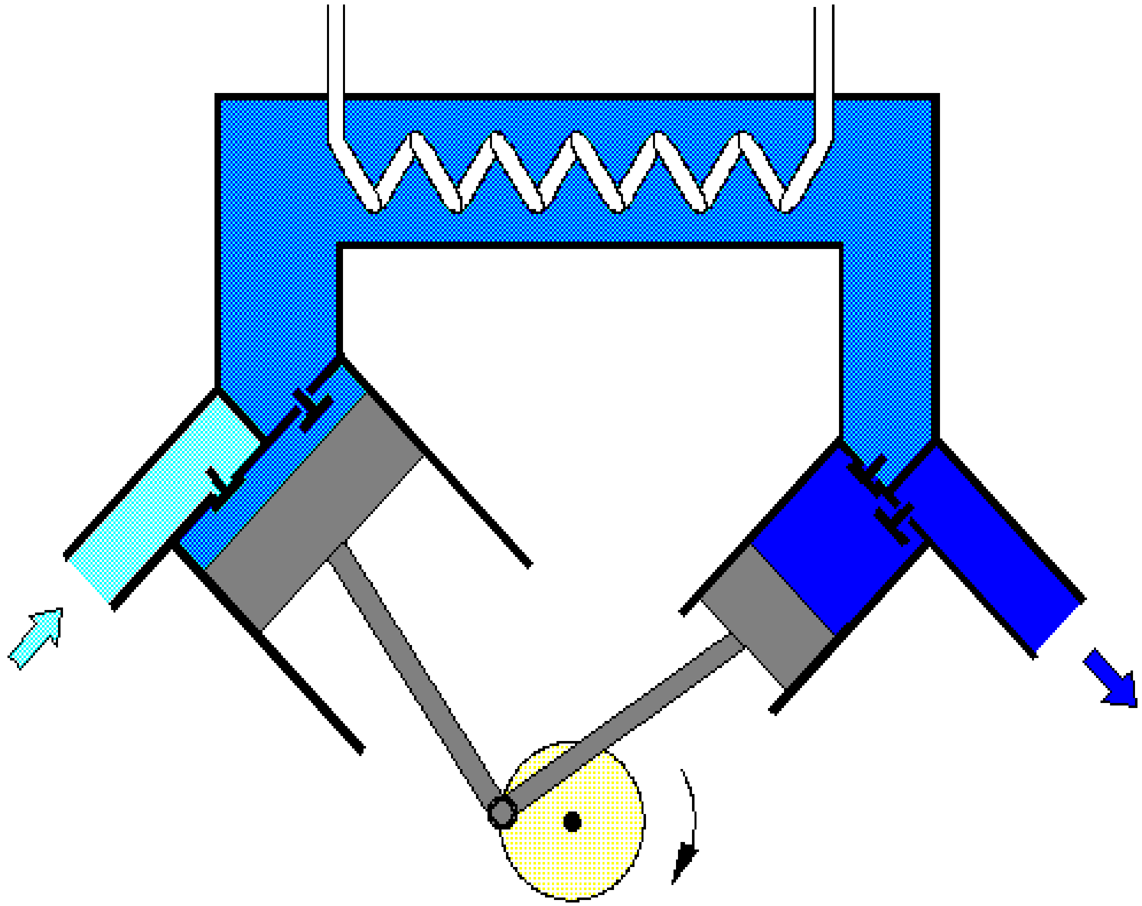
- Fallowing types of compressors are used depending on required flow rate of air and maximum delivery pressure

- Piston type or reciprocating compressor
- Rotary type compressors (vane or screw type)
- Centrifugal type compressor
- Axial flow compressor

Types of compressor

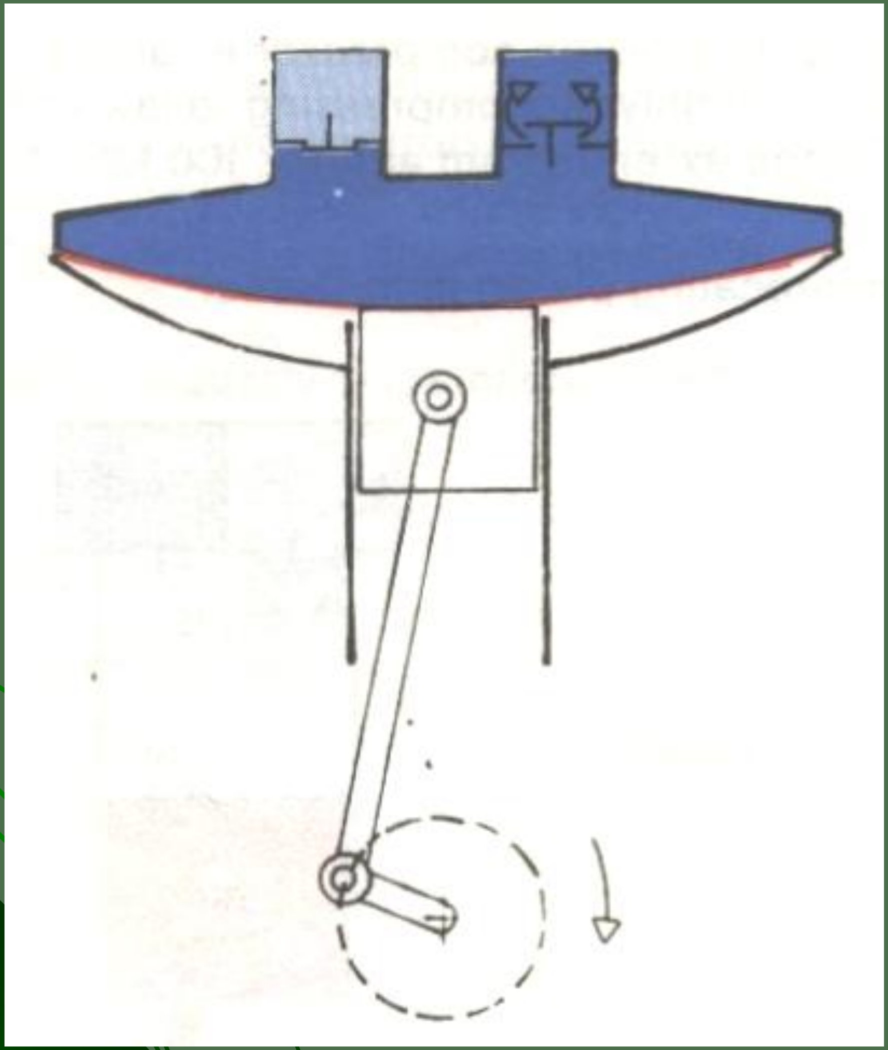


Piston type reciprocating compressor

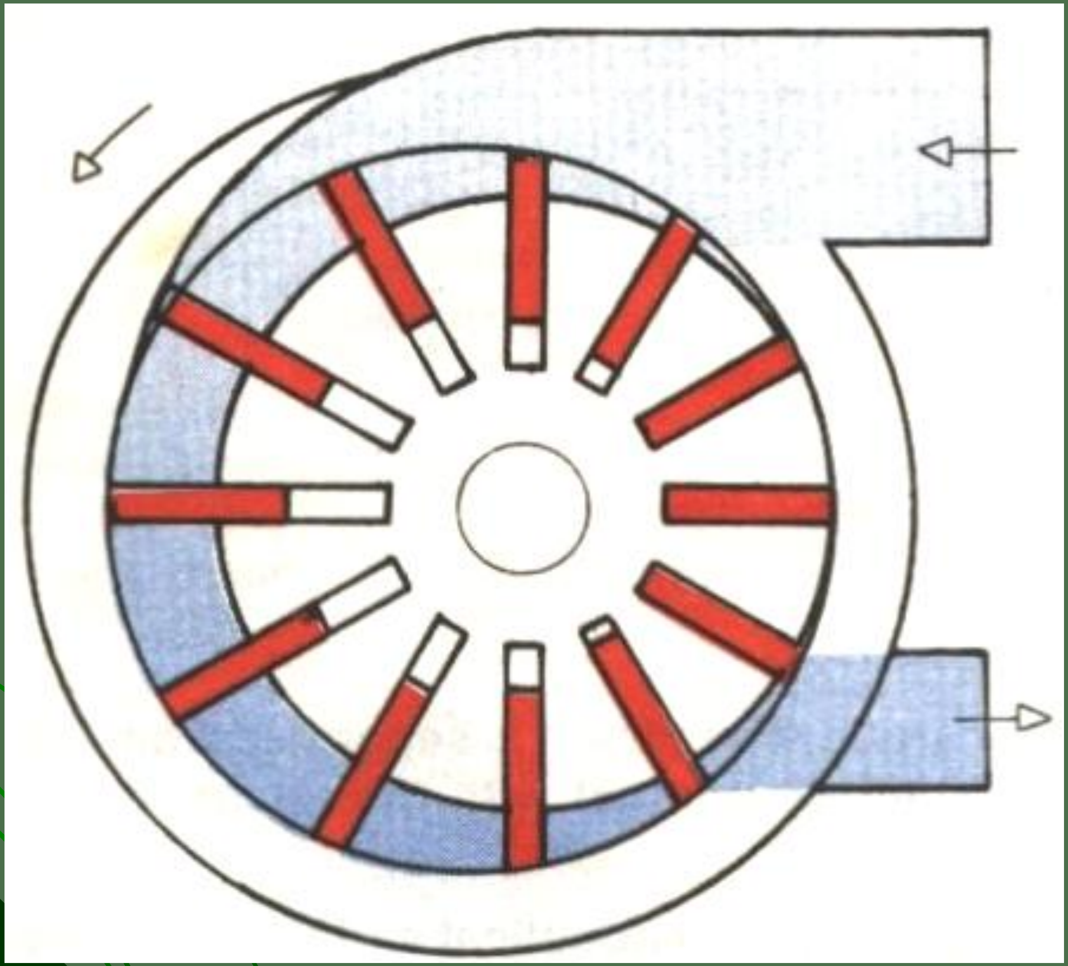


Compressed air supply: Piston compressor

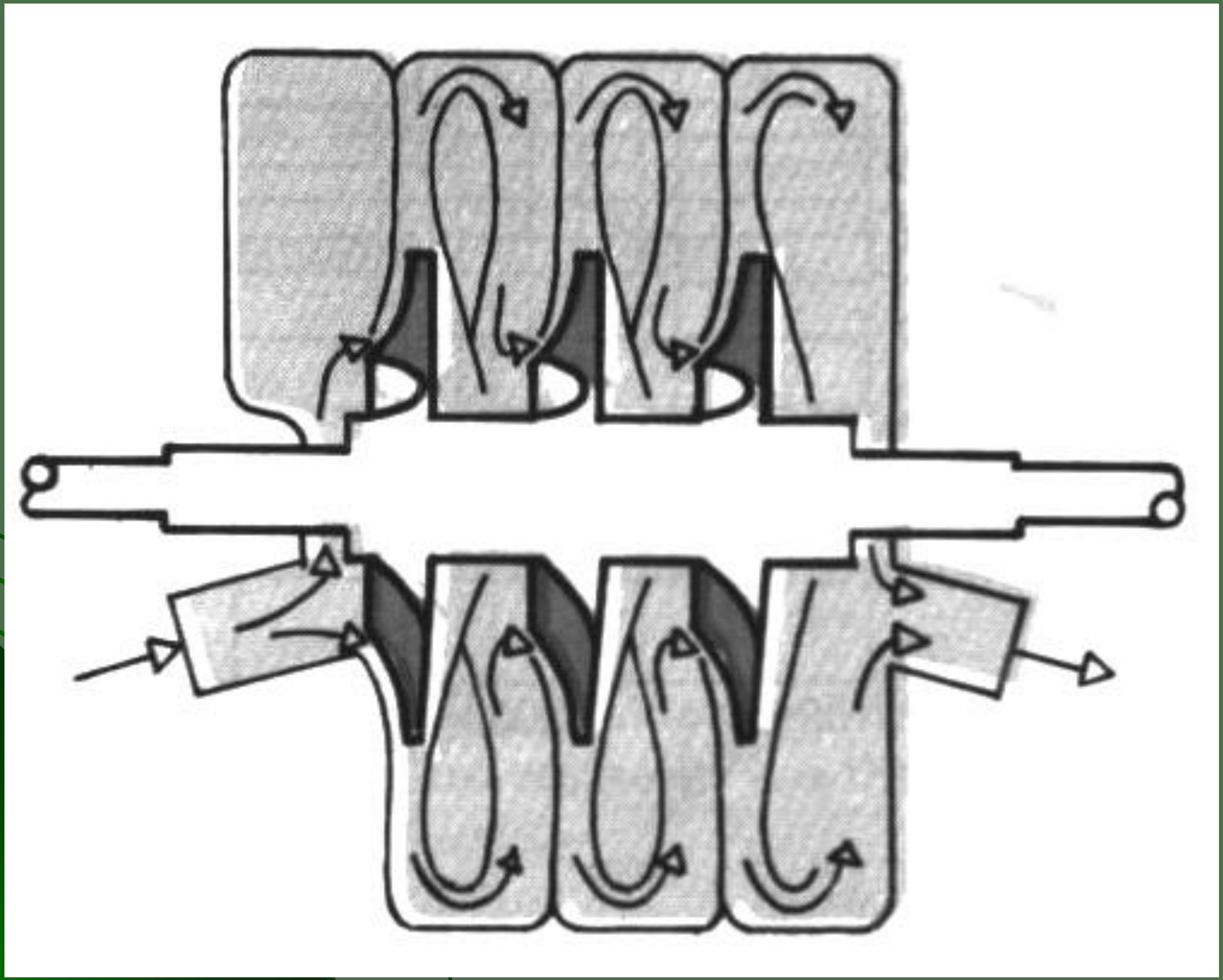
Diaphragm type compressor



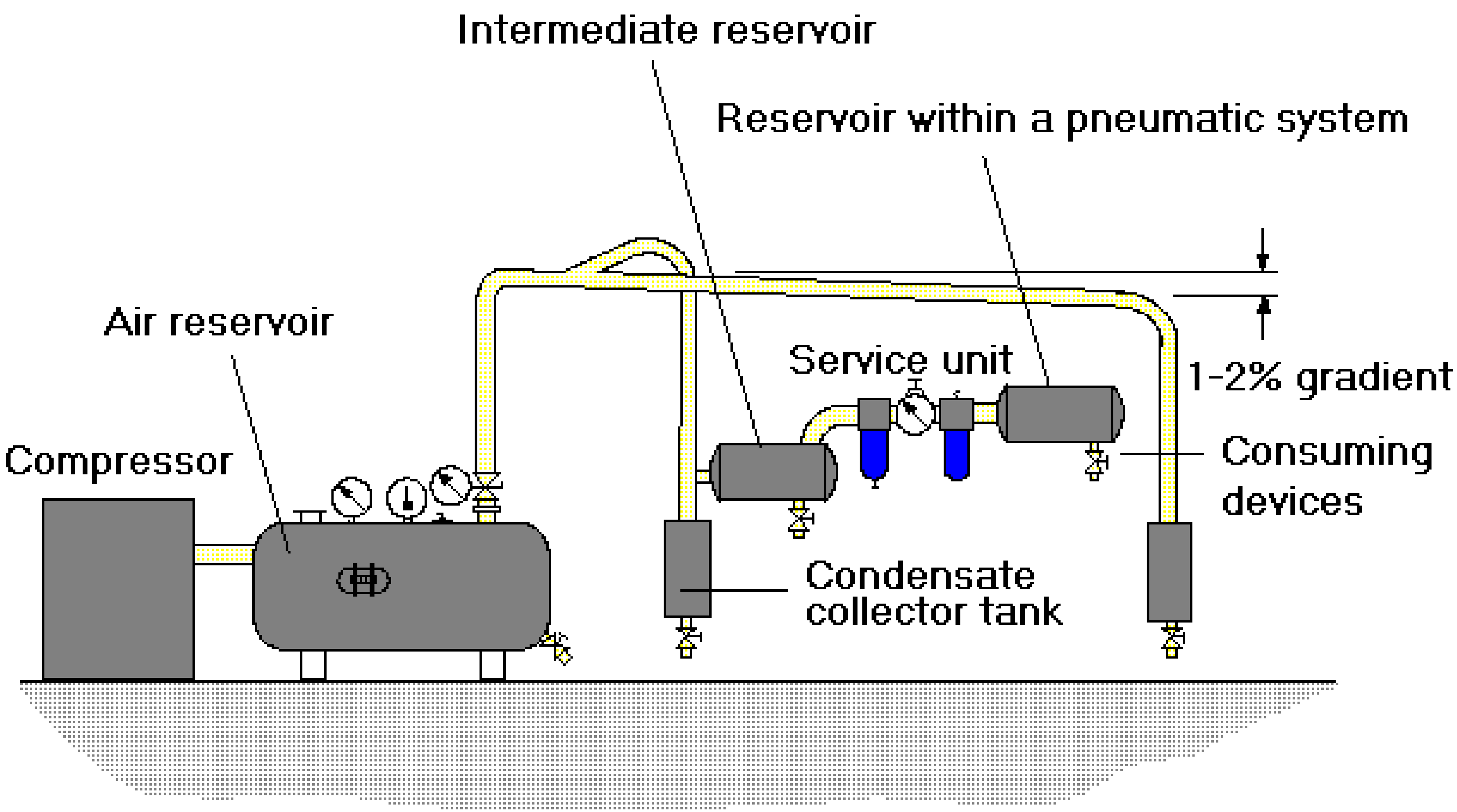
Vane type compressor



Centrifugal compressor



Compressor system

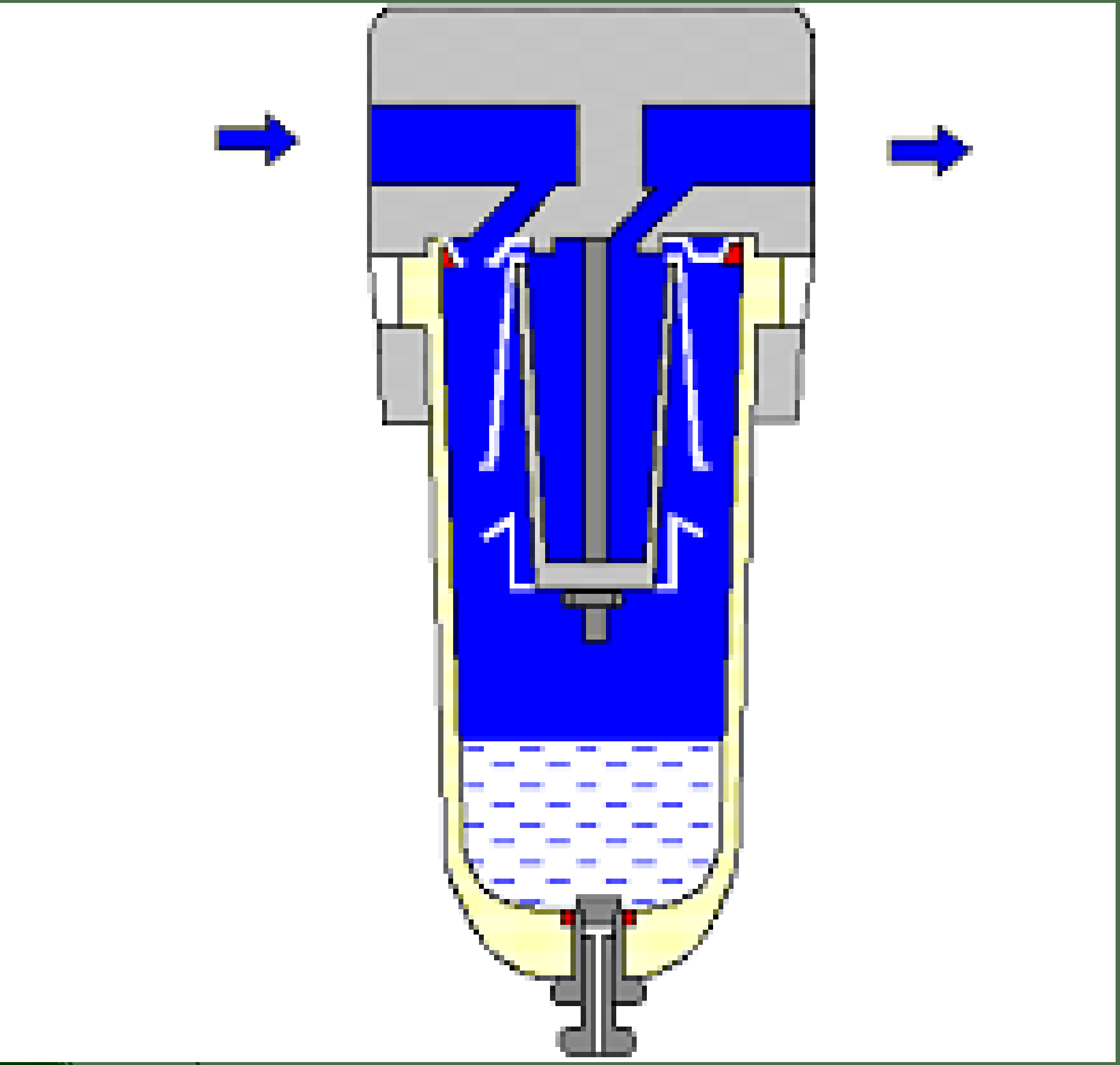


Compressed air supply: Delivery

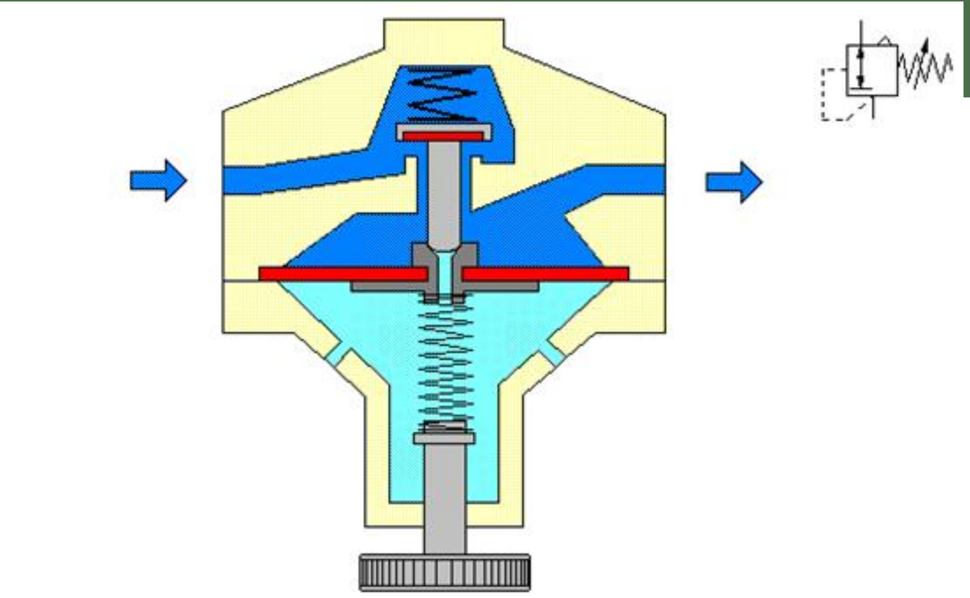
Components of air compression system

- Air Receiver
- Compressed Air Filter
- Compressed Air Regulator
- Compressor Air Lubricator

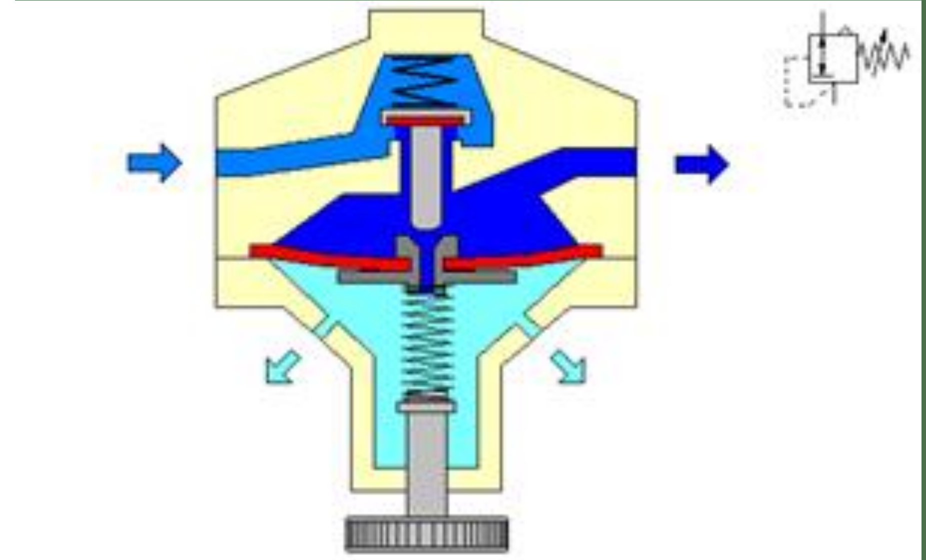
Compressed air filter



Compressed air regulator

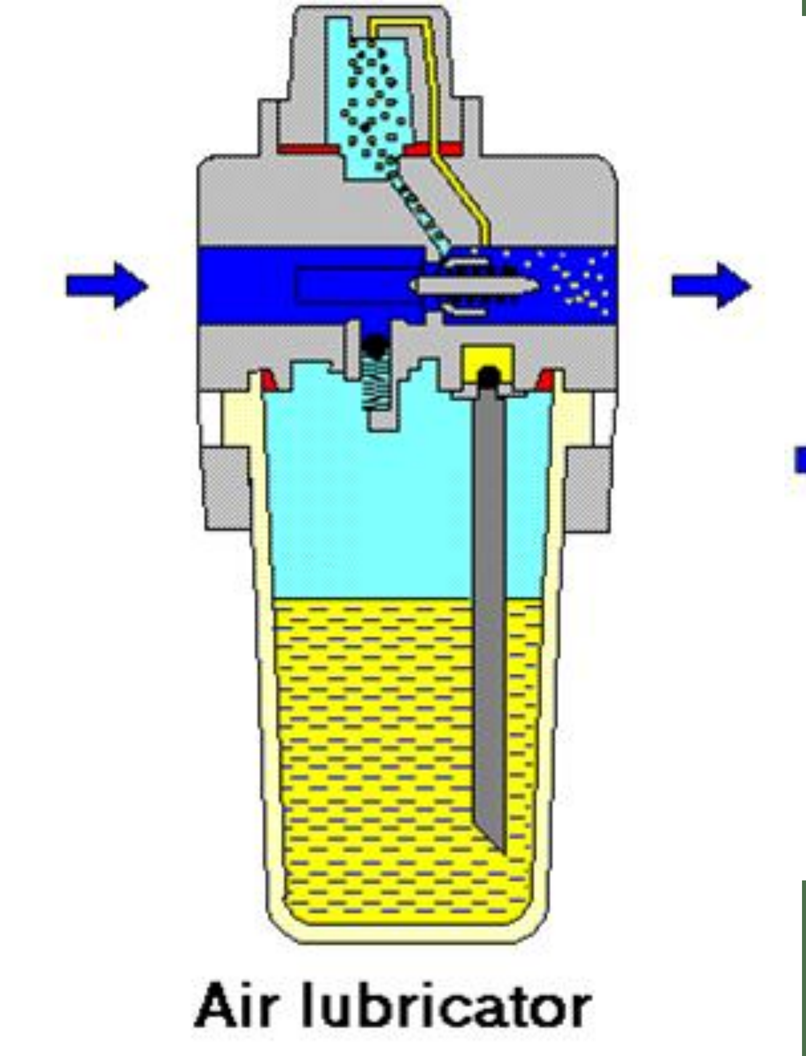


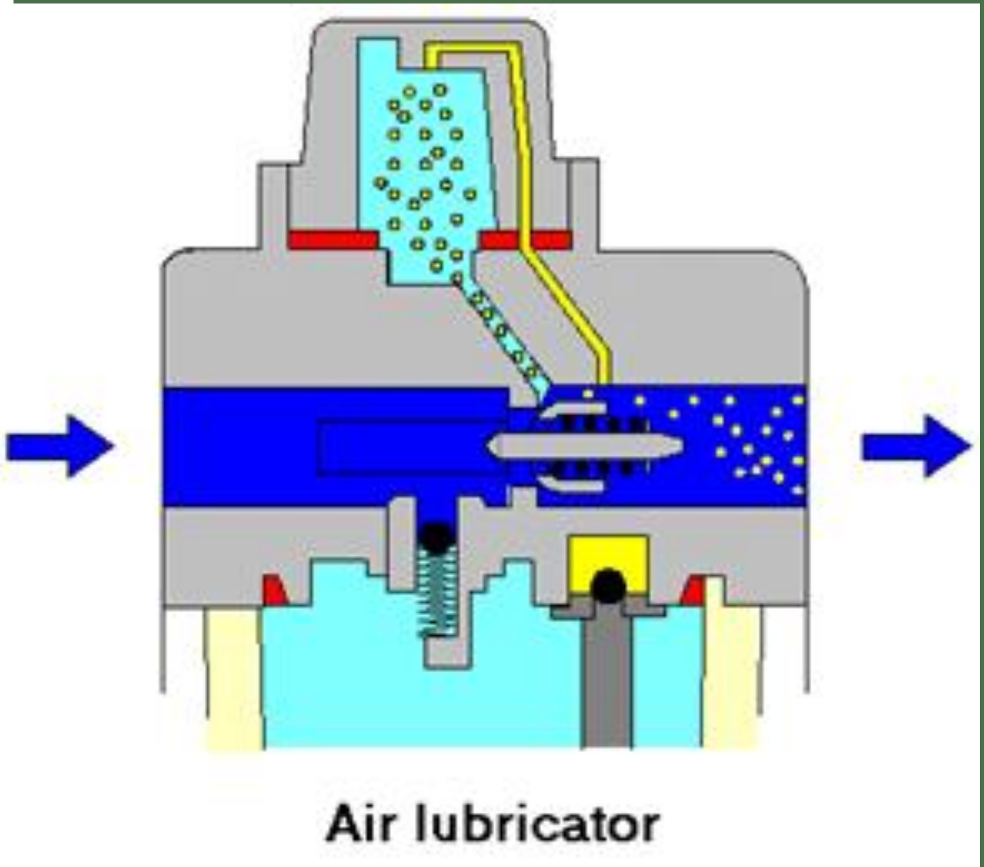
Air supply: Pressure regulator with vent hole



Air supply: Pressure regulator with vent hole

Compressed air lubricator





Coordinated Motion Control

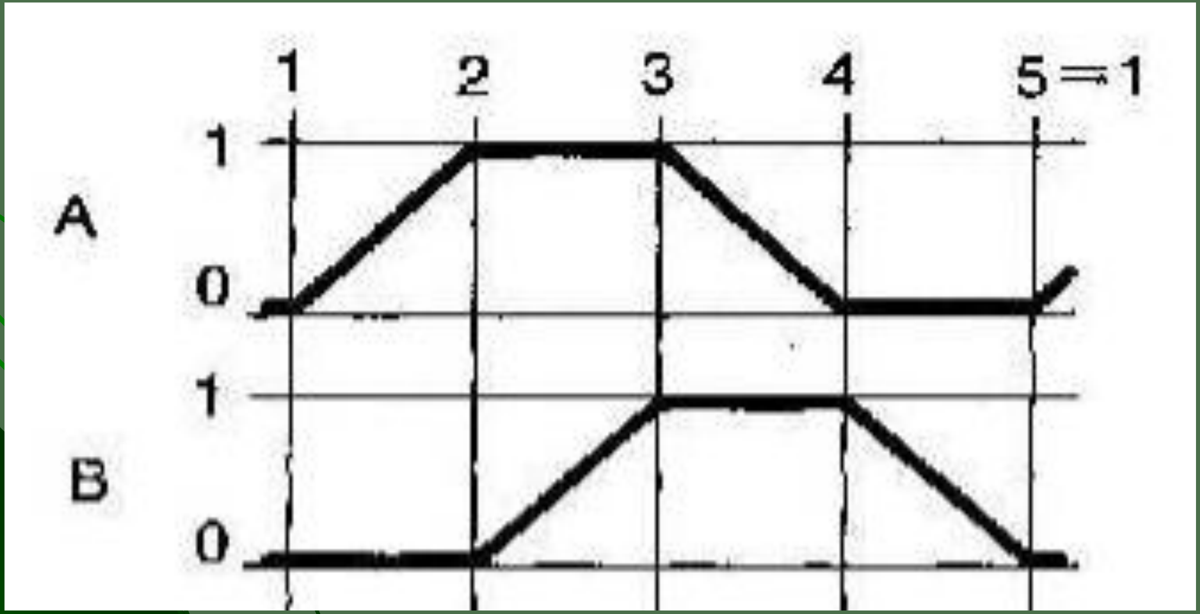
Coordinated Motion Control

- In majority of the pneumatic applications more than one cylinder is used. The movement of these cylinders are coordinated as per the required sequence.
- The activation of limit switches of different cylinders will provide set or reset signal to the final control valves for further controlling the movement of various cylinders.
- The limit switches have to be arranged in the proper location with the help of motion diagram.

Position Step Diagram

In order to develop control circuitry for multi cylinder applications, it is necessary to draw the motion diagram to understand the sequence of actuation of various signal input switches-limit switches and sensors

Motion diagram represents status of cylinder position -whether extended or retracted in a particular step



Sequential Motion of Cylinders

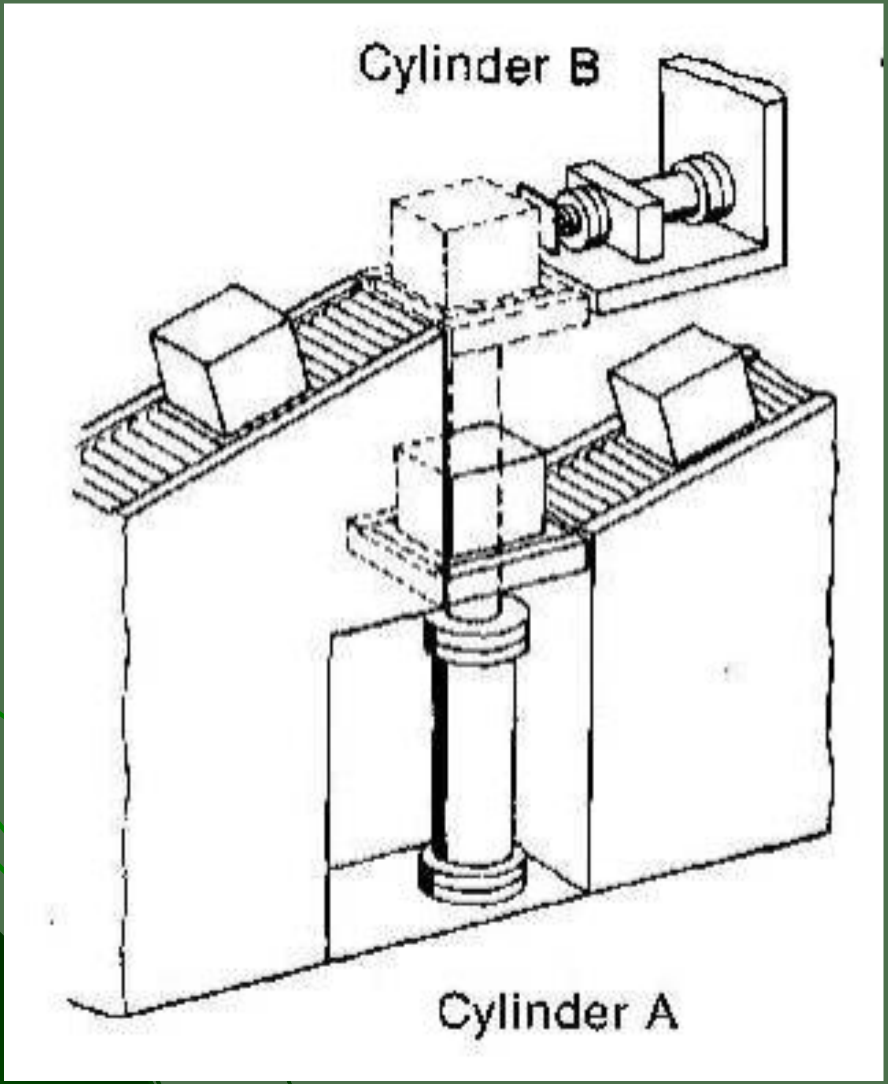
- It is possible to have the following sequence of operation
  with **two** cylinders

Sequence	Example of Application
A+, B+, A-,B-	Lifting & Shifting / shifting of parts in two directions ,
A+, B+. B-,A-	Clamping & Stamping/Riveting
A+, A-, B+, B-	Feeding and Ejection of parts

Lifting and Shifting

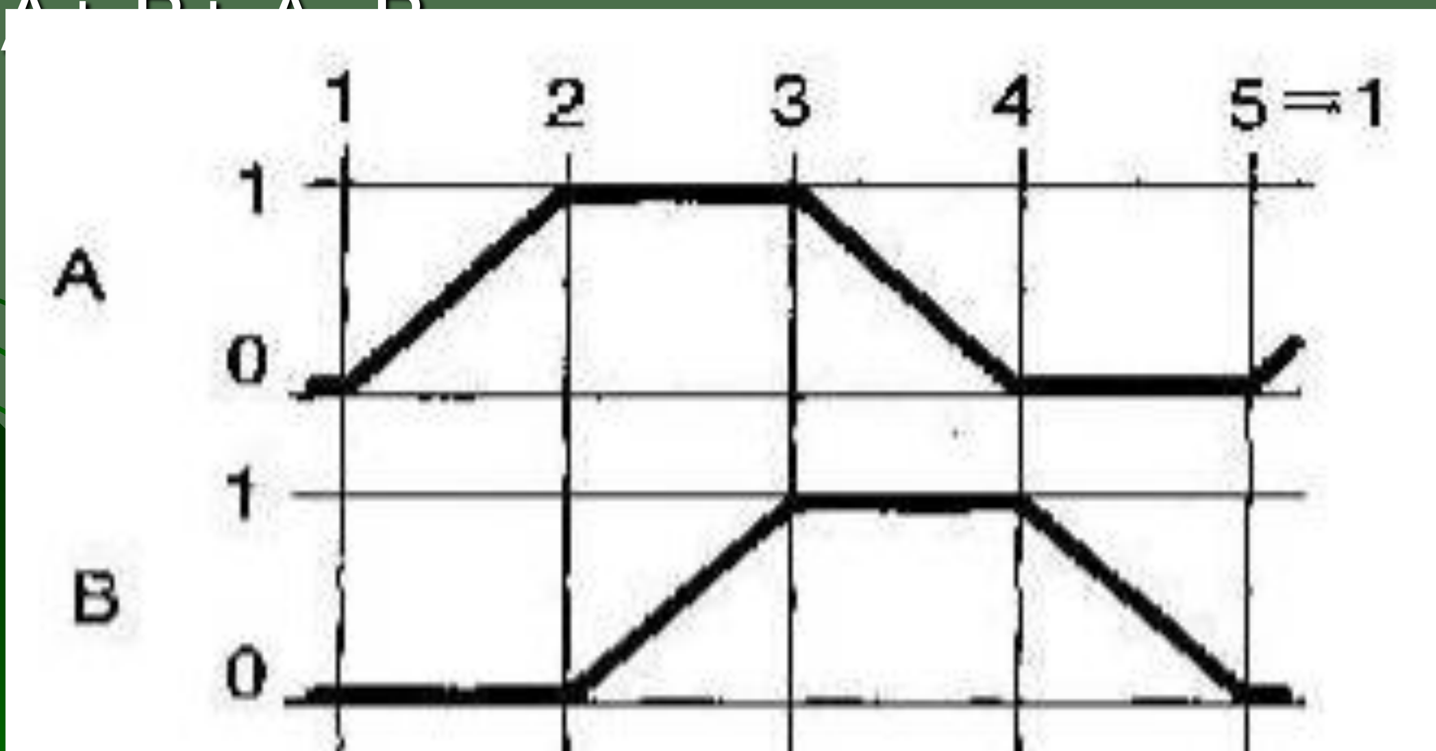
- Products are required to be transferred from lower level conveyor to higher level conveyor using two Pneumatic Cylinders
- Lifting Cylinder A lifts the product on receiving it at lower level
- Shifting Cylinder B shifts the product from the platform to the higher level conveyor
- Lifting cylinder retracts
- Shifting cylinder retracts

Lifting and Shifting

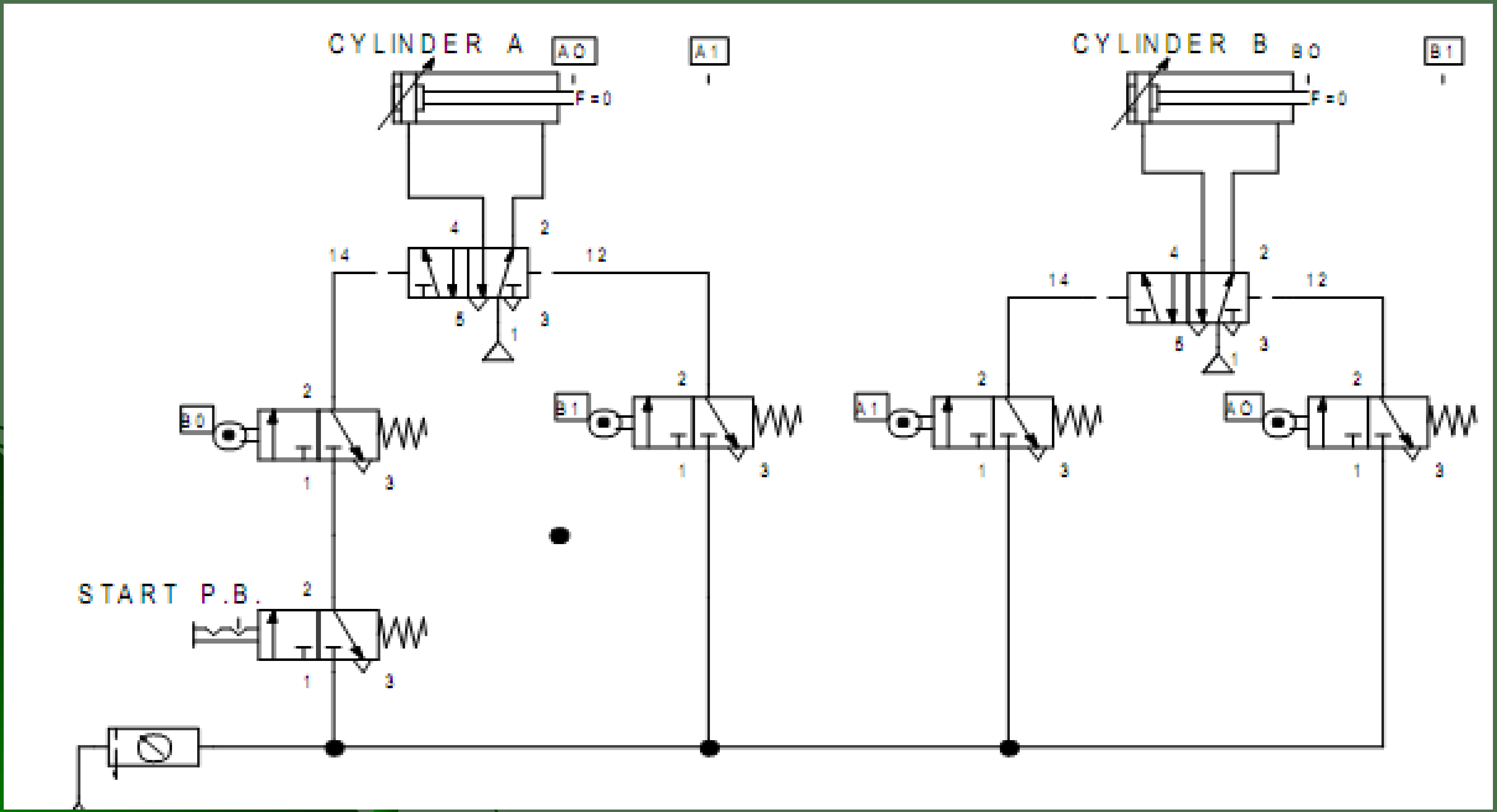


Position Step Diagram Lifting and Shifting

- Motion and Control Diagrams are shown for Lifting and Shifting Application:
  A+ B+ A- B-

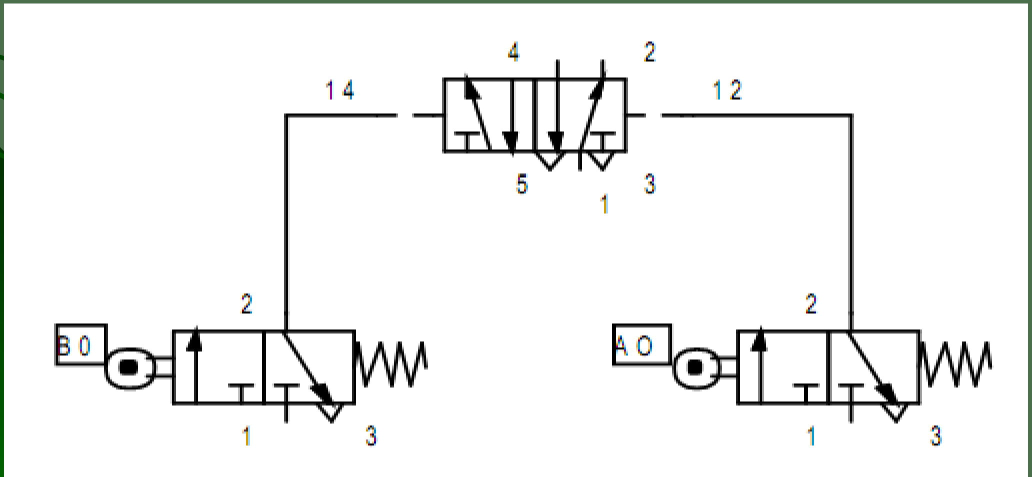


Lifting and Shifting



Signal Overlap

- Signal Overlap can occur when simultaneously two active signals appear on both set and reset pilot ports of Final Control Valve. This is due to the required sequencing of cylinder. At the start, both signals a0 and b0 appear at the same time. This will not result in any change.



Multi Cylinder Applications Signal Elimination

- On analyzing the status of **set** signal and **reset** signal for final control valve for different cylinders, it is observed that both set and reset signals could be present simultaneously at any instant of time, depending on the sequential operation of the cylinder. This does not permit further change in status of the valve. This situation is termed as signal over lap.

Multi Cylinder Applications Signal Elimination

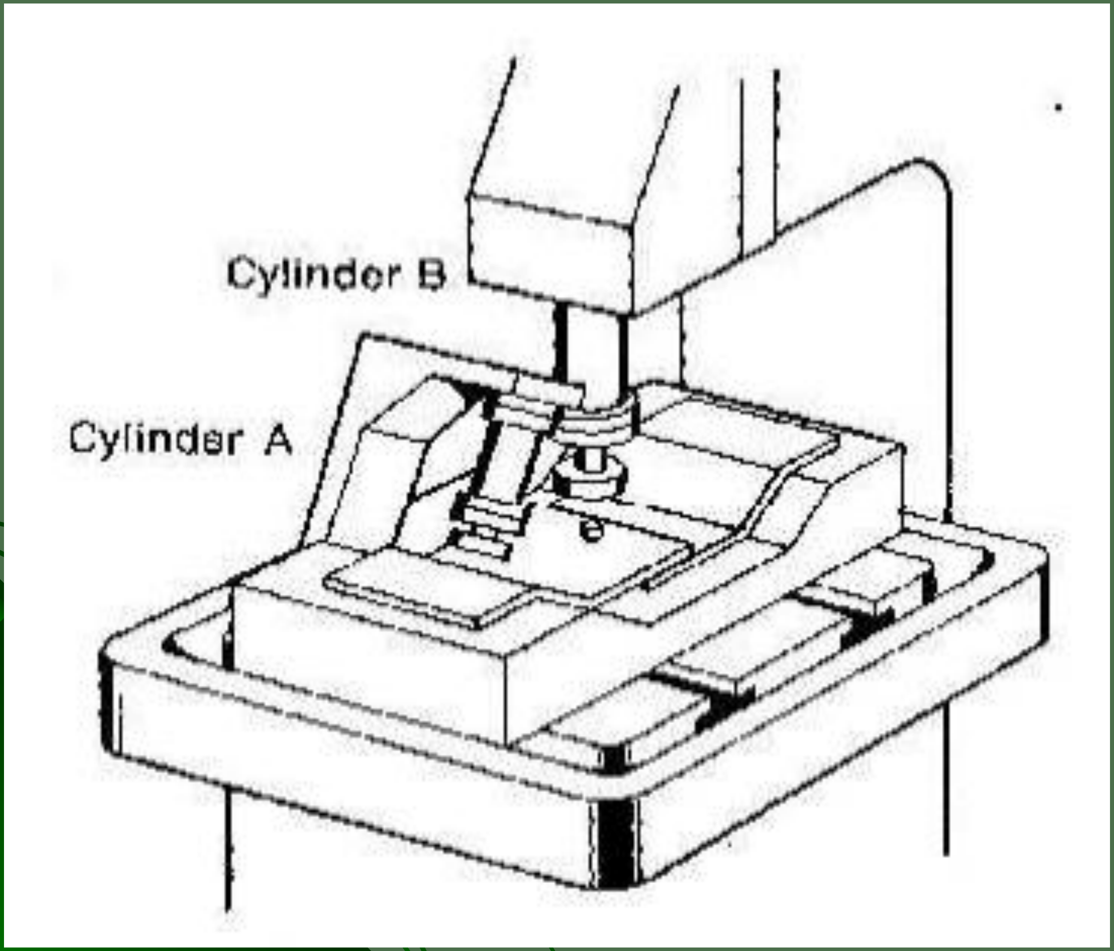
- **Use of Idle return lever limit switches**
- Use of N.O Timers
- Use of Cascading with the help of reversing valves
- Use of Stepper Sequencer modules

Example for signal overlap

- **Clamping and Riveting**

- Sheet metal components are to be riveted using two Pneumatic Cylinders. A Clamping cylinder (A) first advance and clamps the sheet metal parts.
- While the parts are clamped a second cylinder (B) advance and performs riveting operation
- The riveting cylinder retracts and finally clamping cylinder retracts

Clamping and Riveting



Clamping and riveting circuit