

UNIT-1.0

Introduction to Fluid Power System

Fluid - Fluid is a matter which have capability of flow.

Ex - liquid, Gas.

Fluid - [Hydraulics (Liquid/water)
Pneumatics (Gas/oil)

Power - Rate of work done,

Fluid Power - Power exerted by a fluid.

Ex - Dem (water)

Modes of Power Transmission -

- Mechanical :- The power transmission is through shafts, gears, chains, belts, etc.
- Electrical :- Transmission is through wires, transformers etc.
- Fluid :- Fluid power is transmitted through liquids or gas in a confined space.

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* Comparison of Different Power Systems :-

Property	Mechanical	Electrical	Pneumatic	Hydraulic
Input energy source	I.C. Engines Electric motor	I.C. engine water/gas turbines	I.C. engines Pressure tank	I.C. engines Electric motor Air turbine
Energy transfer element	Levers, gears, shafts	Electrical cables & magnetic field	Pipes and hoses	Pipes and hoses
Energy carrier	Rigid and elastic objects	Flow of electrons	Air	Hydraulic liquids
Power-to-weight Ratio	Poor	Fair	Best	Best
Motion type	Mainly rotary	Mainly rotary	Linear / rotary	Linear or rotary
Control	Fair	Best	Good	Good
Stiffness	Good	Poor	Fair	Best
Torque / Inertia	Poor	Fair	Good	Best
Relative cost	Best	Best	Good	Fair
Response speed	Fair	Best	Fair	Good

- Pascal's law:- states that the pressure exerted on a confined fluid is transmitted undiminished in all directions and acts with equal force on equal areas and at right angles to the containing surfaces.

$$P = \frac{F}{A}$$

Here, F = Force acting on the piston

A = Area of piston

P = pressure on the fluid

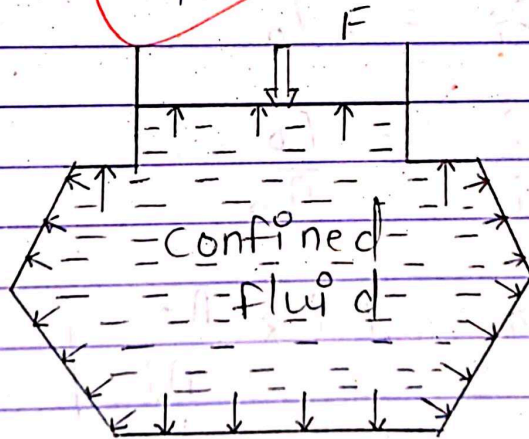
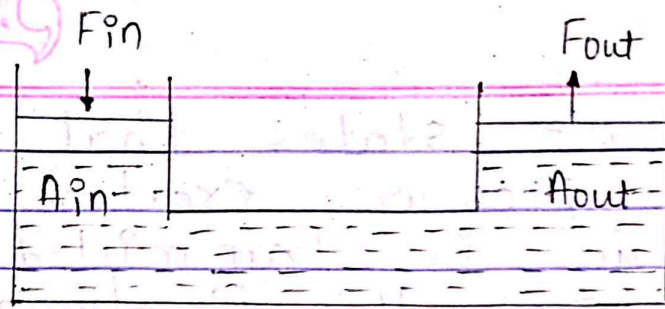


Figure - illustration of pascal's law

- Multiplication of Forces:- The most useful feature of fluid power is the ease with which it is able to multiply forces.



This is accomplished by using an output piston that is larger than the input piston.

Multiplication of Forces

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P_i = P_o$$

$$\frac{F_i}{A_i} = \frac{F_o}{A_o}$$

$$F_o = F_i \times \frac{A_o}{A_i}$$

$$\therefore \frac{A_o}{A_i} > 1$$

$$\therefore \begin{aligned} A_i &< A_o \\ F_i &< F_o \end{aligned}$$

$$(Vol)_{in} = (Vol)_{out}$$
$$A_{in} \cdot x_{in} = A_o \cdot x_o$$

$$* \left[\frac{x_i}{x_o} = \frac{A_o}{A_i} = \frac{F_o}{F_i} \right]$$

Q. An input cylinder with a diameter of 30mm is connected to an output cylinder with a diameter of 80mm. A force of 1000N is applied to the input cylinder.

- (a) What is the output force?
- (b) How far do we need to move the input cylinder to move the output cylinder 100 mm?

Solve - Given that

Input cylinder diameter, $d_i = 30\text{mm}$

Output cylinder diameter, $d_o = 80\text{mm}$

Applied to the forces of Input cylinder, $F_i = 1000\text{N}$

Area of input, $A_i = \frac{\pi}{4} \times (d_i)^2$

$$= \frac{\pi}{4} \times (30)^2$$

$$A_i = 225\pi \text{ mm}^2$$

Area of output, $A_o = \frac{\pi}{4} \times (d_o)^2$

$$A_o = 1600\pi \text{ mm}^2$$

$$1. \text{ Output Force} = \frac{F_o}{F_i} = \frac{A_o}{A_i}$$

$$F_o = \frac{A_o}{A_i} \times F_i$$

$$F_o = \frac{1600\pi}{225\pi} \times 1000 = 7111.11 \text{ N} \quad \text{Ans.}$$

2. Input cylinder to move -

output cylinder move $x_o = 100 \text{ mm}$

$$\frac{x_o}{x_i} = \frac{F_o}{F_i}$$

$$x_i = \frac{F_o}{F_i} \times x_o = \frac{7111.1}{1000} \times 100$$

$$x_i = 711.1 \text{ mm}$$

Ans.

Q. Two hydraulic cylinders are connected at their piston ends (cap ends rather than rod ends) by a single pipe. Cylinder A has a diameter of 50mm. & cylinder B has a diameter of 100mm. A retraction force of 2222N is applied to the piston rod of cylinder A. Determine the following -

(a) Pressure at cylinder A.

(b) " " " " B.

(c) Pressure in the connection pipe.

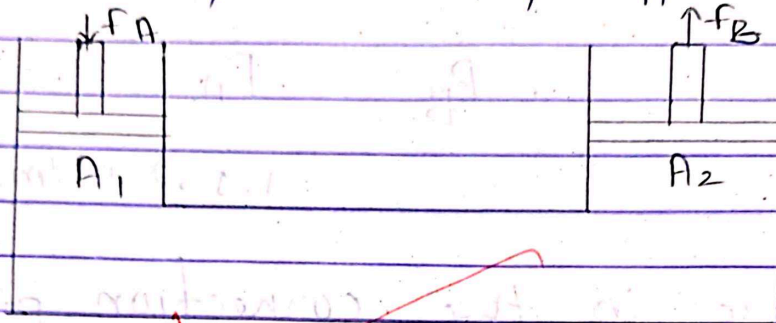
(d) Output force of cylinder B.

Solve - Given that -

Diameter of cylinder A, $d_A = 50 \text{ mm}$

Diameter of cylinder B, $d_B = 100 \text{ mm}$

Force of cylinder A, $F_A = 2222 \text{ N}$



Area of piston of cylinder A = $\frac{\pi}{4} \times (d_A)^2$

$$A = \frac{\pi}{4} \times 50^2 \text{ mm}^2$$

Area of piston of cylinder B = $\frac{\pi}{4} \times (d_B)^2$

$$B = \frac{\pi}{4} \times 100^2 \text{ mm}^2$$

(a) Pressure at cylinder A -

$$P_A = \frac{\text{Force at cylinder A}}{\text{Area of cylinder A}}$$

$$P_A = \frac{2222}{\frac{\pi}{4} \times (50)^2} = 1.132 \text{ N/mm}^2$$

Ay

(b) Pressure at cylinder B -

By pascal's law

Pressure at cylinder B = Pressure at cylinder A

$$P_B = P_A$$

$$= 1.132 \text{ N/mm}^2$$

Ans.

(c) Pressure in the connection pipe -

By pascal's law

$P_A = P_B = \text{Pressure at the pipe line (P)}$

$$\therefore P = P_A = 1.132 \text{ N/mm}^2 \quad \text{Ans.}$$

(d) Output force of cylinder B -

$$\Rightarrow \frac{F_{OB}}{A_{OB}} = \frac{F_{IA}}{A_{IA}} \Rightarrow F_{OB} = \frac{A_{OB}}{A_{IA}} \times F_{IA}$$

$$F_{OB} = \frac{\frac{\pi}{4} \times (100)^2}{\frac{\pi}{4} \times (50)^2} \times 2222$$

$$F_{OB} = 8888 \text{ N}$$

Ans

Q. A force of $P = 850 \text{ N}$ is applied to the smaller cylinder of a hydraulic jack. The area of the small piston is 15 cm^2 and the area of the larger piston is 150 cm^2 . What load w can be lifted on the larger piston (a) If the pistons are at the same level.

(b) if the larger piston is 0.75 m below the smaller one? The mass density ρ of the liquid in the jack is 103 kg/m^3 ?

Solve - Given that

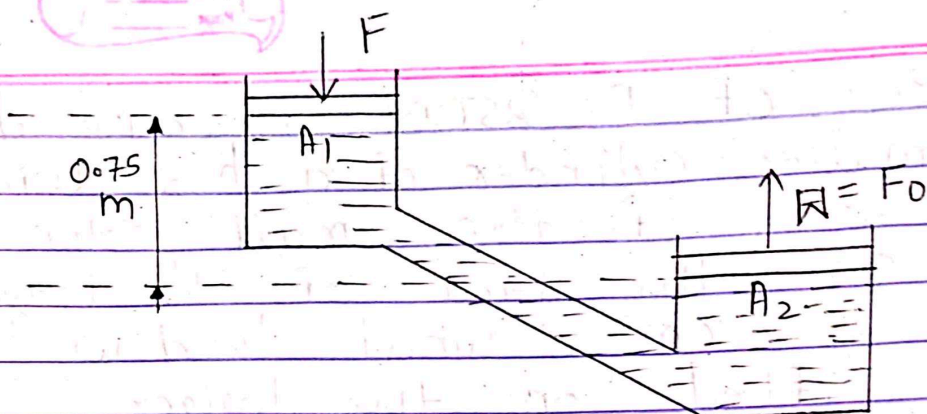
Area of small piston, $A_1 = \frac{\pi}{4} \times (d_1)^2 = \frac{\pi}{4} \times (15)^2$

$$A_1 = 15 \text{ cm}^2 = 0.15 \text{ m}^2$$

Area of larger piston, $A_2 = 150 \text{ cm}^2$
 $A_2 = 0.15 \text{ m}^2$

$$\text{Force, } F = 850 \text{ N}$$

$$\therefore P = P_1 = P_2$$



(a) we know that,

$$P_1 = \frac{F}{A_1} \quad \& \quad P_2 = \frac{W}{A_2}$$

$$\therefore \frac{F}{A_1} = \frac{W}{A_2}$$

$$\Rightarrow W = \frac{F \times A_2}{A_1} = \frac{850 \times 1.05}{0.15}$$

$$\boxed{W = 8500 \text{ N}} \quad \text{Ans.}$$

(b) Piston are at different level -

$$P_1 = \frac{F}{A_1} = \frac{850}{15 \times 10^{-4}} = 56.66 \times 10^4$$

$$\therefore P_2 = P_1 + \rho g h = 56.66 \times 10^4 + 103 \times 9.81 \times 0.75$$

$$P_2 = 567357.822 \text{ N/m}^2$$

$$P_2 = \frac{F_0}{A_2} \quad [F_0 = W]$$

$$F_0 = P_2 \times A_2$$

$$F_0 = 567357.822 \times 0.015$$

$$F_0 = 8510.36 \text{ N.} \quad \text{Ans.}$$

- Factors affecting the Fluid Flow:-

1. Gravity :- Fluid will flow from high gradient to low gradient.

2. Atmospheric Pressure :- Fluid will flow from high pressure to low pressure.

3. Inertia :- More amount of power is required for flowing of high inertial fluid & vice versa.

Inertia $\propto$ mass

4. Viscosity :- High amount of power is required for flowing of high viscous fluid & low amount of power is required for less viscous fluid.

$$\text{Viscosity} \propto \frac{1}{\text{Fluid flow}}$$

5. Friction :- For easy flow of fluid the pipe surface should be smooth other wise it will cause high energy loss in fluid flow.

- Advantages of a fluid power system:-

1. Fluid power system are simply, easy to operate and can be controlled accurately :-

Fluid power gives flexibility to equipment without requiring a complex mechanism using fluid power; we can stop, start, accelerate, decelerate, reverse or position large forces / components with great accuracy using simple levers and push buttons.

For example; in earth moving equipments

2. Multiplication and variation of forces :-

Linear or rotary force can be multiplied by a fraction of a kilogram to several hundreds of tons.

3. Low speed torque :- Unlike electric motors air or hydraulic motors can produce a large amount of torque while operating at low speeds.

4. Constant force or torque :- fluid power system can deliver constant torque or force regardless of speed changes.

5. Economical :- Not only reduction in required manpower but also the production or elimination of operator fatigue as a production factor, is an important element in the use of fluid power.

6. Low weight to power ratio :-

The hydraulic system has a low weight to power ratio compared to electromechanical system.

- Applications of fluid Power :-

1. Agriculture - Tractors; farm equipment such as mowers, ploughs, chemical and water sprayers, fertilizer spreaders, harvesters.
2. Automation - Automated transfer lines, robotics.
3. Automobile - Power steering, Power brakes, Suspension system, hydrostatic transmission.
4. Defense - Missile - launching systems, navigation controls.
5. Glass industry - Vacuum suction cups for handling.
6. Oil - industry - Off - shore oil rigs
7. Plastic industry - Automatic injection molding machines, raw material feeding, jaw closing.
8. Transportation - Hydraulic elevators, winches, overhead cranes.

* Basic Components of a fluid power system-

→ Components of a Hydraulic System:-

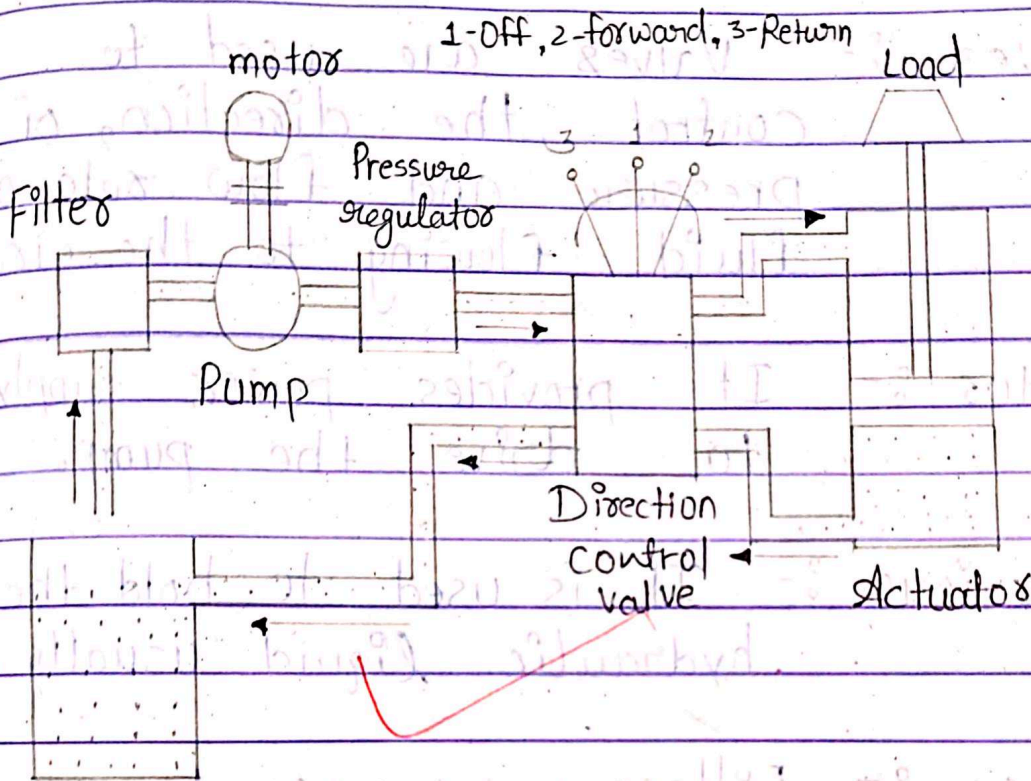


Figure:- Components of a hydraulic system

1. **Actuator** :- It is a device used to convert the fluid power into mechanical power to do useful work.

2. **Hydraulic Pump** :- Pump is used to force the fluid from the reservoir to rest of the

OF the hydraulic circuit by converting mechanical energy into hydraulic Energy.

3. Valves :- Valves are used to control the direction, of pressure and flow rate of fluid flowing to the circuit.

4. Motor :- It provides power supply to drive the pump.

5. Reservoir :- It is used to hold the hydraulic liquid usually oil.

6. Filters :- Filters are use to remove any foreign particles so as keep the fluid system clean and efficient, as well as avoid damage to the actuator & valves.

7. Pressure Regulators :- It regulates the required level of Pressure in the hydraulic fluid.

→ Components of a Pneumatic System :-

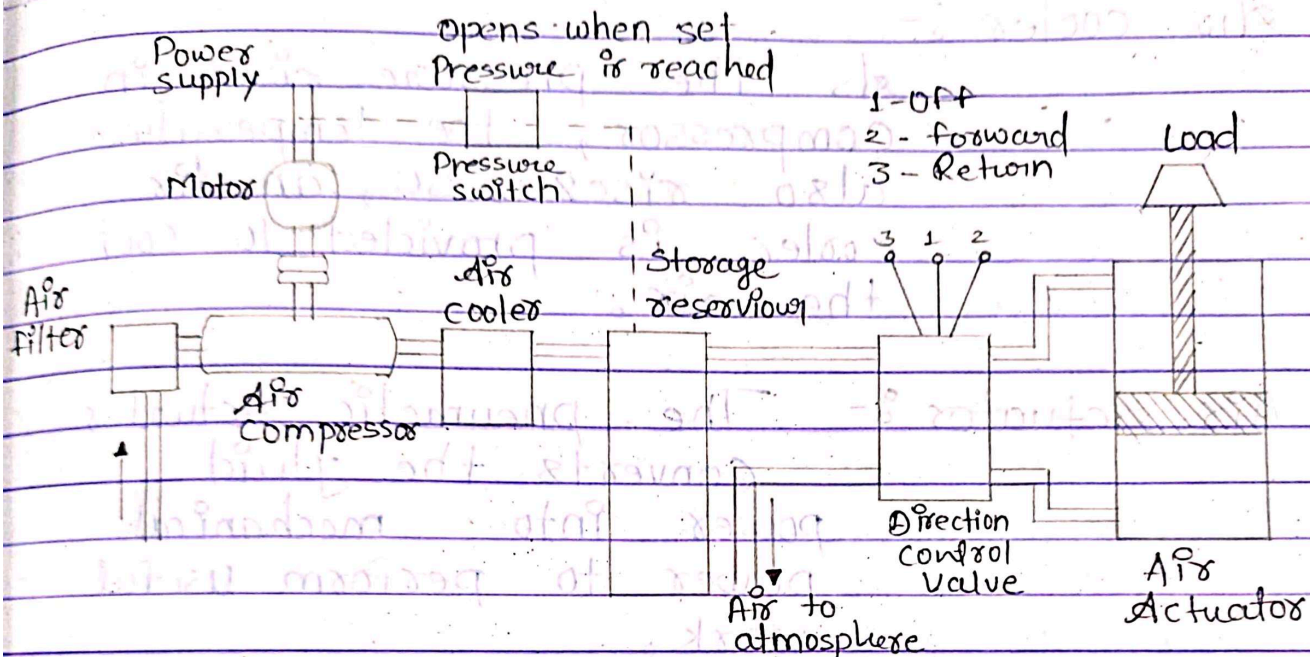


Figure :- Components of Pneumatic System

1. Air Compressor :-

It compresses the fresh air drawn from the atmosphere.

2. Storage Reservoir :-

It is used to store a compressed volume of given air.

3. Pressure switch :-

It regulates the pressure in pneumatic circuit.

4. Air cooler :-

As the pressure rises in compressor, the temperature also rises. So, an air cooler is provided to cool the air.

5. Air Actuator :- The pneumatic actuator converts the fluid power into mechanical power to perform useful work.

6. Valves :- valves are used to control the direction of pressure & flow rate of air flowing to the circuit.

7. Motor :- The external power supply motor is used to drive the compressor.

8. Air Filters :- Filters are used to remove the dust particles from the air. So as to keep the air fresh & clean, & well as avoid damage to the actuator & valves.

* Hydraulic Fluids :-

→ Functions :-

1. Power Transmission :-

It is the primary and important function of Fluid.

2. Lubrication :-

To lubricate various parts, so as to avoid metal to metal contact and reduce friction, wear and heat generation.

3. Sealing :- To seal the moving elements to avoid leakage.

4. Cooling :- To carry away the heat generated in the system and to dissipate heat through reservoir or a heat exchanger.

5. Contaminant Removal :- To carry along the contaminations, to the tank, where they can be removed through filters.

→ Properties :-

1. Ideal Viscosity :-

The most basic desirable property of a hydraulic fluid is optimum viscosity. Viscosity is a measure of a fluid's resistance to flow. When viscosity is low, the fluid flows easily. On the other hand, when viscosity is high, the fluid flows with difficulty. So, the viscosity of the fluid should be high enough to seal the working gaps b/w parts and prevent leakage. But should be low enough to cause easy flow to the system. Therefore hydraulic fluid should have an optimum viscosity.

* ISO & SAE grade oil

ISO - International Standard Organisation -

ISO v.g. 2 - ISO v.G. 1500 -

Represents the kinematic viscosity

SAE - Society of Automotive Engineers (U.S.A.)

2. Demulsibility :-

The ability of a hydraulic fluid to separate rapidly from moisture and successfully resist emulsification is known as 'Demulsibility'.

If an oil emulsifies with water the emulsion promotes the destruction of lubricating and sealant properties. Highly refined oils are basically water resistance by nature.

3. Good chemical and Environmental Stability :-

For a good hydraulic fluid, a good chemical and environmental stability is desirable. Most fluids are vulnerable to oxidation, as they come in contact with oxygen in air. Mineral oils or petroleum-based oils (widely used in hydraulic systems) contain carbon and hydrogen molecules, which easily react with oxygen. The oxidation products are highly soluble in oil and being acidic in nature they can easily corrode metallic parts.

Dust and corrosion cause excessive leakage between moving parts. Dust and corrosion can be prevented by incorporating additives that plate on the metal surface to prevent chemical reaction.

4. Neutralization Number :-

Neutralization number is a measure of the acidity or alkalinity of hydraulic oil. This is referred to as the pH value of the oil. High acidity causes the oxidation rate in oil to increase rapidly.

5. Incompressibility :-

Though we consider hydraulic fluids as incompressibility, in practice, they are relatively compressible. Most mineral oils undergo reduction in the volume of about 0.7% for every 100 bar rise in pressure. In fact, the compressibility of a fluid is greatly influenced by temperature & pressure.

The incompressibility of a fluid is a measure of its stiffness & is given by its bulk modulus. The bulk modulus (β) of a fluid is the ratio of volumetric stress to volumetric strain and is given by the relation

$$\beta = \frac{V dP}{dV}$$

Here,

β = bulk Modulus,

dP = change in pressure,

V = Original volume,

dV = change in volume (m^3)

6. Fire Resistance :-

There are many hazardous applications where human safety requires the use of a fire-resistant fluid. Examples include coal mines, hot metal processing equipment, aircraft and marine fluid power systems. A fire-resisting fluid is one that can be ignited but does not support combustion when the ignition source is removed.

7. Low Flammability :-

A fire-resistant fluid is one that can get ignited in the presence of an ignition source but does not support combustion when the source is removed. This characteristic is defined as flammability. It refers to the ease with which a fluid gets ignited & propagates the flame. Hence, it is desirable to have a low flammability for a hydraulic fluid.

8. Foam Resistance :-

Air can be present in a hydraulic fluid in two forms: dissolved and entrained. For example, if the return line to the reservoir is not submerged, the jet of oil entering the liquid surface will carry air with it. This causes air bubbles to form in the oil. If these bubbles rise to the surface too slowly, they will be drawn into the pump intake. This can cause pump damage due to cavitation. Another adverse effect of entrained and dissolved air is a

great reduction in the bulk modulus of the hydraulic fluid.

9. Low Volatility :-

A fluid should possess low vapour pressure or high boiling point. The vapour pressure of a fluid varies with temperature and hence the operating temperature range of the system is important in determining the stability of the fluid.

10. Good Heat Dissipation :-

A hydraulic fluid should have a high heat dissipation capability. The temperature of a fluid shoots up if its heat dissipation characteristics are poor. Too high fluid temperature can cause a system to malfunction.

11. System Compatibility :-

A hydraulic fluid should be inert to materials used in or near the hydraulic equipment. If the fluid in anyway attacks, destroys,

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dissolves or changes the parts of hydraulic system, the system may lose its functional efficiency and may start malfunction.

→ Types of Hydraulic Fluids :-

1) Petroleum based fluid :- Mineral oils are the petroleum based oil that are the most commonly used hydraulic fluid. Because they possess the most of desirable properties & they are easily available & economical. The only & major disadvantage of this fluid is its flammability.

2) Emulsions :- It is a mixture of two fluids that do not chemically react with each other. Emulsion of petroleum based oil and water are commonly used. It has two types :-
1. Oil in water emulsion.
2. Water in oil emulsion.

3) Water Glycol :- Water glycol is another non-flammable fluid commonly used in aircraft hydraulic system. It has water & glycol in the ratio of 1:1. It has a low lubrication ability & not suitable for high temperature application.

4) Synthetic Fluid :- It is based on phosphate ester, is another popular fire resistant fluid. It is suitable for high temperature application, since it exhibits good viscosity & lubrication property at high temperature.

5) Vegetable Oil (Biodegradable Oil) :- These fluids are biodegradable & environment safe fluids, like sunflower oil, soyabean, rapeseed oil they have good lubrication & moderate viscosity & less expensive fluids.

→ Factors Influencing the Selection of Fluid :-

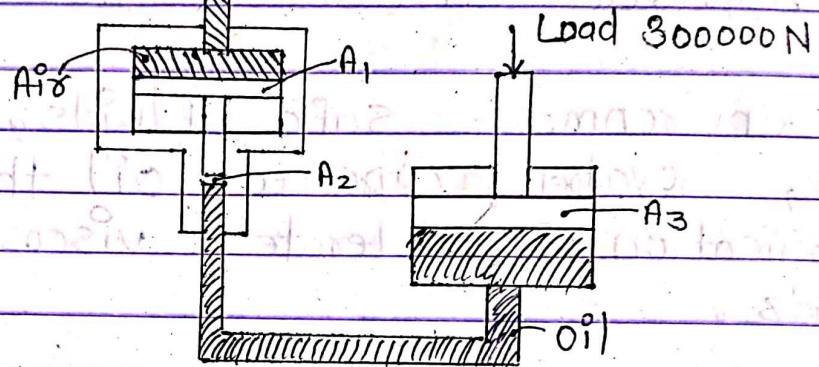
1. Operating pressure of the system.
2. Operating temperature of the system.
3. Material of the system.
4. Cost of transmission lines.
5. Contamination possibility.
6. Environmental condition.
7. Speed of operation.
8. Lubricity.
9. Safety to operator.
10. Expected service life.

Q. For Pressure booster following data are given -

1. Inlet oil Pressure (P_1) = 1 MPa
2. Air Piston area (A_1) = 0.02 m^2
3. Oil Piston area (A_2) = 0.001 m^2
4. load carrying capacity = 300000 N

Find the piston Area $A_3 = ?$.

Solve -



Given -

$$P_1 = 1 \text{ MPa}, A_1 = 0.02 \text{ m}^2, A_2 = 0.001 \text{ m}^2$$
$$L = 300000 \text{ N}$$

The force acting on A_1 is equal to the force acting on A_2 .

$$\begin{aligned} F_1 &= F_2 \\ P_1 A_1 &= P_2 A_2 \end{aligned} \quad \left[\begin{array}{l} P = F/A \\ F = PA \end{array} \right]$$

$$1 \times 0.02 = P_2 \times 0.001$$

$$P_2 = \frac{0.02}{0.001} = 20 \text{ MPa}$$

According to pascal law the pressure acting at A_2 is equal to pressure acting at A_3 .

$$\therefore P_2 = P_3$$

$$20 \times 10^6 = \frac{300000 \text{ N}}{A_3}$$

$$A_3 = \frac{300000 \text{ N}}{20 \times 10^6 \text{ N/m}^2} = 0.015 \text{ m}^2$$

Ans.

→ Disadvantages of fluid power system:-

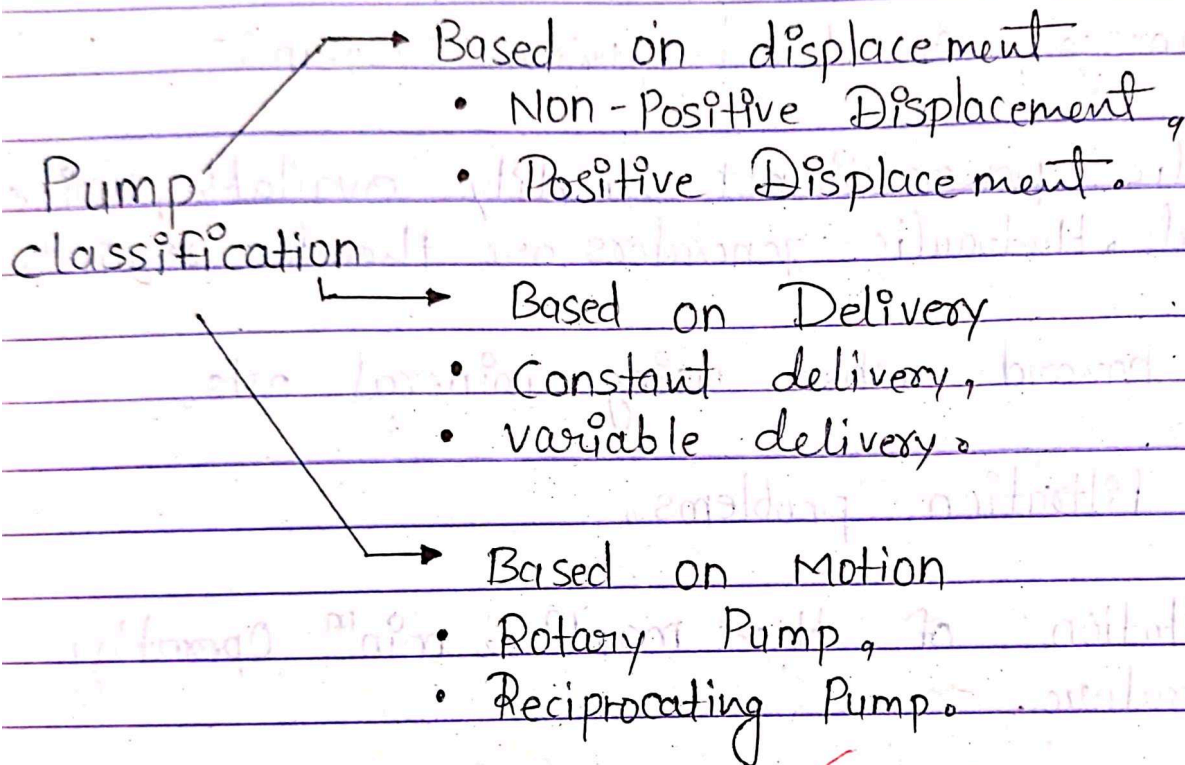
1. Hydraulic power is not readily available, unlike electrical. Hydraulic generators are therefore required.
2. Fire hazard when using mineral oils.
3. Oil filtration problems.
4. Limitation of the max^m & min^m operating temperature.
5. High inertia of transmission lines, which increases their response time.
6. High cost of production due to the requirements of small clearances & high precision production process.

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Elements of Hydraulic Systems

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1. Pump :- The function of pump is to convert mechanical energy into hydraulic energy. It is the heart of any hydraulic system, because it generates the force necessary to move the loads.



→ Positive displacement pump :-

Positive displacement pumps are called positive because of "no fluid comes back to its casing during pumping out". A locking is formed by meshing gear, sliding vanes & parts that acts like a seal and whole amount of fluid goes through delivery line. This amount is called positively.



displaced amount and that's why it is called positive displacement pump.

Ex - reciprocating pump, gear pump.

U-good

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→ Non-Positive Displacement pump :-

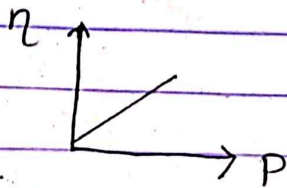
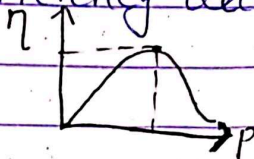
In Non-positive displacement pump a small amount of fluids gets back into the casing due to its casing design. It is design so to churn the fluid in casing even when delivery valve is fully closed without causing any damage to the pump.

Ex - Centrifugal Pump etc.

→ Comparison between positive & non positive displacement pump :-

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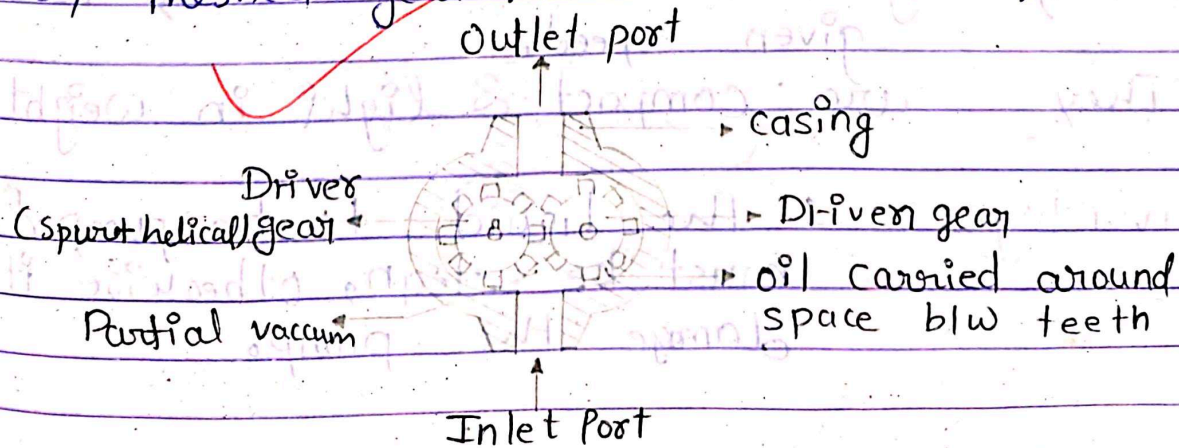
S.No.	Parameters	Positive displacement Pump	Non-positive displacement pump
1.	Pressure	Work in high pressure Application, up to 800 bar.	It is used for low pressure Application, max ^m pressure up to 18 to 20 bar.
2.	Head	It is used in high head application.	It is used in low head application.
3.	Discharge	It discharges low amount of fluid.	It discharges large amount of fluid.
4.	volumetric Efficiency	It has low volumetric efficiency in comparison to Non-positive displacement pump.	It has high volumetric efficiency in comparison to positive displacement pump.
5.	Mechanical efficiency	Efficiency increases with increasing pressure.	Efficiency peaks at best efficiency point. At higher or lower pressure, efficiency decreases.

6.	Viscosity	Efficiency increases with increasing viscosity.	Efficiency decreases with increasing viscosity due to frictional losses inside the pump.
7.	Delivery flow	Flow delivery is constant with changing pressure.	Flow delivery varies with changing pressure.
8.	Priming	Positive pumps are self priming pump.	Priming is required in this pump.

→ Gear Pump - There are two types -
1. External gear pump, 2. Screw gear pump

- External Gear Pump - It consists of a pump (Construction & working) housing in which a pair of precisely meshed gears runs with min^m radial clearance



One of the gears called a driver, is driven by a prime mover. The driver drives another gear called a follower (driven gear), as the teeth of two gears separate the fluid from the pump inlet gets trapped b/w the rotating gear cavity & pump housing.

The trapped fluid is then carried around the periphery of the pump casing & delivered to outlet port.

The teeth of precisely meshed gear provide almost a perfect seal b/w inlet & outlet port.

Advantages -

1. They are self priming.
2. They give constant delivery for a given speed.
3. They are compact & light in weight.

Disadvantages - 1. The liquid to be pumped must be clean, otherwise it will damage the pump.

2. Variable speed drives are required to change the delivery.

3. If they run dry, parts can be damaged because the fluid to be pumped is used as lubricant.

- Screw Gear Pump :-

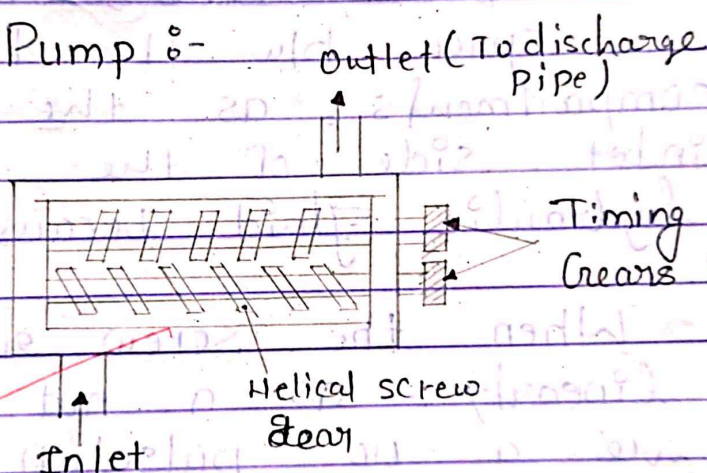


Figure- screw Pump

Components - 1. Pump housing, 2. Timing gears
3. Inlet port, 4. Outlet port
5. Helical meshing screw (Here 2 gear)

The shown screw pump have 2 helical meshing screw in a close fit to develop the desired pressure.

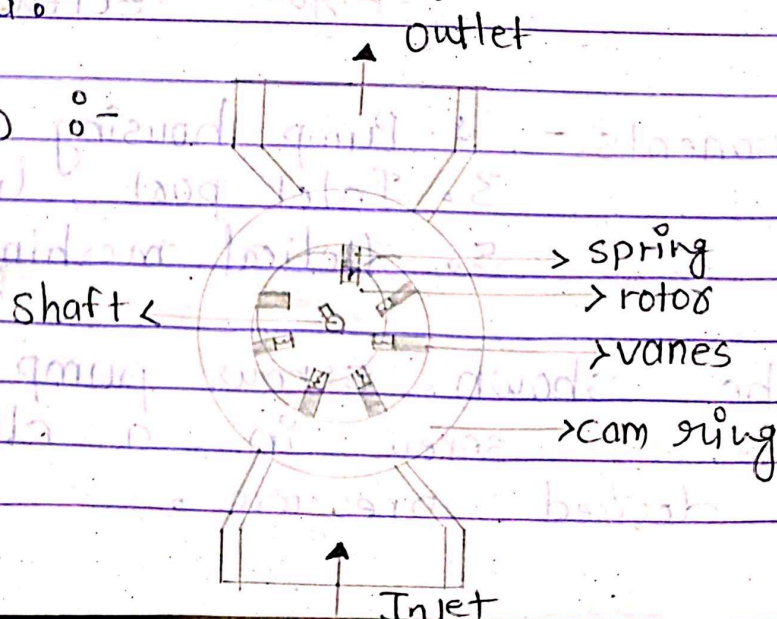
It consists of two parallel rotors with intermeshing thread rotating in a closely machine casing.

The driving screw and the driven screw are connected by means of timing gears.

Working :- When the screws turn the space b/w the threads is divided to compartments. as the screws rotates the inlet side of the pump is flooded with hydraulic fluid because of partial vacuum.

When the screw rotates the fluid moves linearly as a nut on threads. Thus, there are no pulsation at a higher speed and it create high pressure at delivery end.

→ Vane Pump :-



- Components of Vane Pump :-

1. Cam ring
2. Radial vanes
3. Spring
4. Rotor
5. Inlet port
6. Outlet port

- Construction :- The main components of pump are the cam ring & radial slotted rotor each radial slot contains a vane which is free to slide in or out of the slots due to centrifugal force the vane is designed to mate with surface of the cam ring as the rotor turns. The cam ring axis is offset to the drive shaft axis.

- Working :- When the rotor rotates the centrifugal force pushes the vanes out against the surface of cam ring. The vanes divide the space b/w the rotor and the cam ring into a series of small chambers.

During the 1st half of the rotor the volume of this chamber increases, thereby causing a reduction of pressure which causes the fluid to flow to flow through the inlet port.

During the second half of rotor rotation the cam ring pushes the vanes back into the slots and the trapped volume is reduced. This ejects the trapped fluid through the outlet port.

→ Piston Pump :-

The piston pump can be defined as it is a positive displacement pump. These pumps use a piston, diaphragm, otherwise plunger for moving liquids.

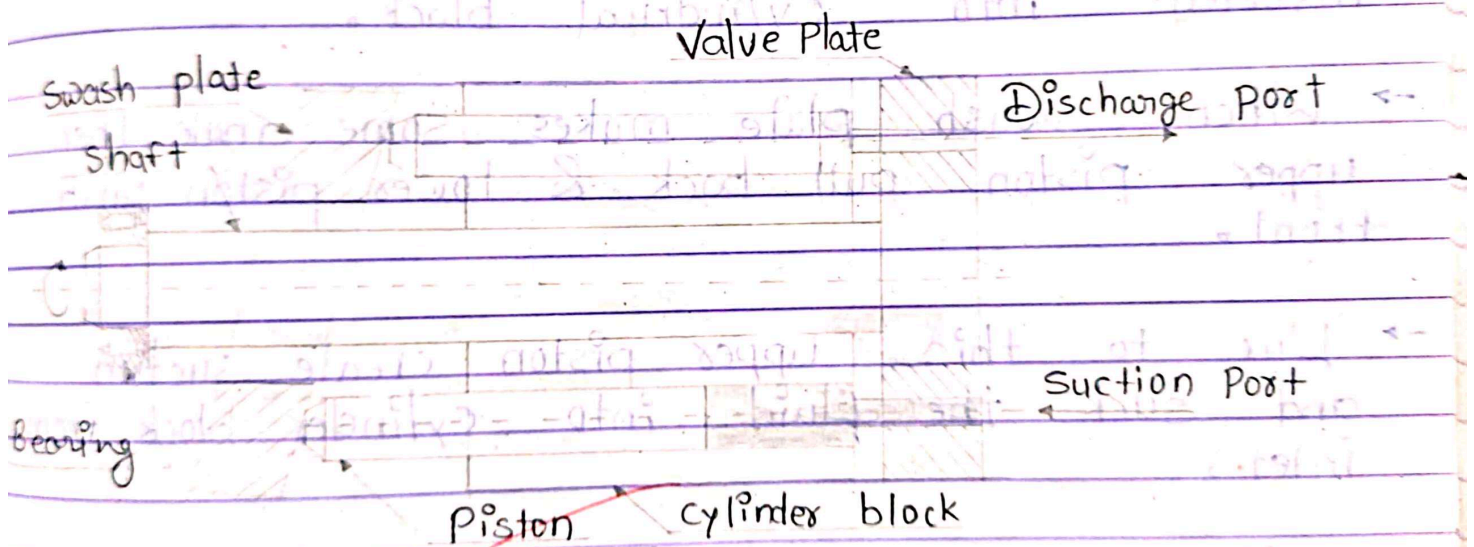
These pumps use check valves as the input & output valves. The general piston-pump is a rotary pump which uses a wheel or revolving shaft for operating the piston.

- ▶ It is used for high pressure applications.
- ▶ It has a rotary unit which uses the principle of the reciprocating pump to produce fluid flow.
- ▶ Instead of using a single piston, these pumps have many piston cylinder combination.

- The part of pump mechanism rotates about a drive shaft to generate the reciprocating motion, which draw the fluid into each cylinder one by one.

Piston Pump $\begin{cases} \rightarrow \text{Axial Piston Pump} \\ \rightarrow \text{Radial Piston Pump} \end{cases}$

Axial Piston Pump :-

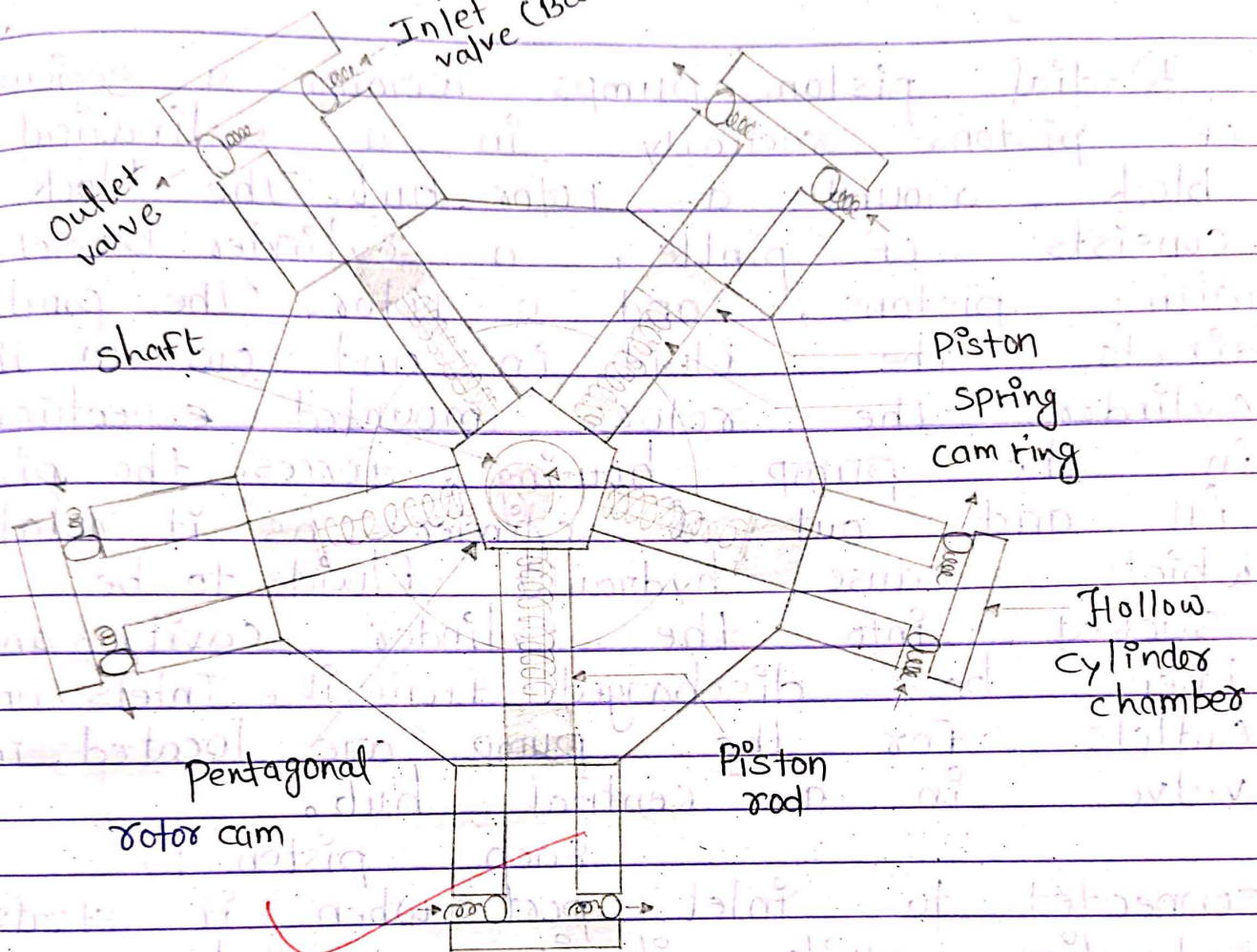


- Components :- 1. Rotating shaft, 2. Swash plate, 3. Cylindrical block; which contains:-
 - (a) odd number of pistons
 - (b) suction port
 - (c) discharge port

► Working :-

- In this pump, there is a swash plate on which number of pistons are connected at equal distance from the center of swash plate (circular plate).
- One side of piston is connected on the swash plate and another side of piston is inserted into cylindrical block.
- When swash plate makes some angle then upper piston pull back & lower piston push front.
- Due to this, upper piston create suction and suck the fluid into cylinder block from inlet.
- The swash plate is connected to input shaft which rotate all pistons & cylindrical block.
- Due to which, upper piston come at bottom & pushed or pumped the liquid at discharge side. Lower piston pushed front due to inclination of swash plate.

Radial Piston Pump :-



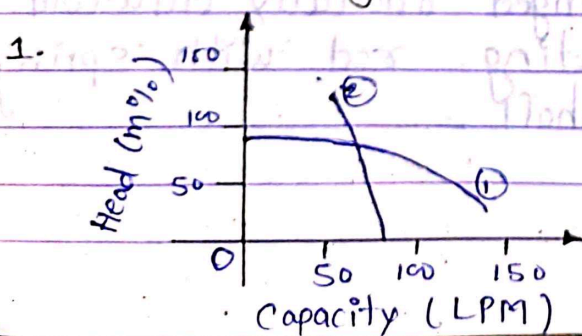
- Components :-
1. Pentagonal rotor cam
 2. Cam ring
 3. Inlet valve
 4. Outlet valve (Ball type)
 5. Pistons arranged radially outward
 6. Piston connecting rod with spring
 7. Rotating shaft

► Working :-

Radial piston pumps arrange a series of pistons radially in a cylindrical block around a rotor hub. The block consists of pintle, a cylinder barrel with pistons, and a rotor. The pintle directs the fluid in and out of the cylinder. The rotor, mounted eccentrically in the pump housing, forces the pistons in and out of cylinders as it rotates, which cause hydraulic fluid to be sucked into the cylinder cavity and then be discharged from it. Inlets and outlets for the pump are located in a valve in a central hub.

Each piston is connected to inlet port when it starts extending while it is connected to the outlet port when start retracting.

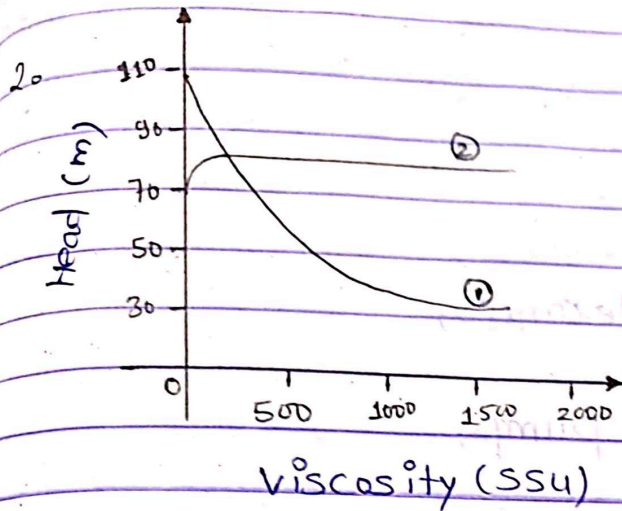
→ Operating characteristics curve for pump :-



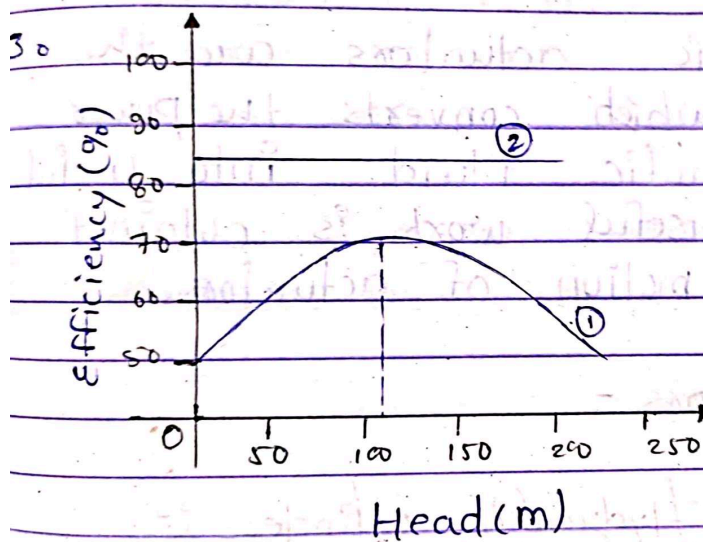
* LPM = Litre per minute

① Non-positive displacement pump

② positive displacement pump



* M.K.S. unit of viscosity
saybolt universal
second (SSU)



→ Selection of Pump :-

The main parameters affecting the selection of a particular type of pump are as follows :-

- 


1. Max^m operating system,
 2. Max^m delivery,
 3. Type of control,
 4. Pump drive speed,
 5. Type of fluid,
 6. pump contamination tolerances,
 7. pump noise,
 8. Size and weight of pump,
 9. pump efficiency,
 10. Maintenance & spares.

→ Actuators :- Hydraulic actuators are the device which converts the power of pressurized hydraulic fluid into useful mechanical work. The useful work is obtained through force and motion of actuators.

→ Classification of Actuators -

1. Linear Actuators or Hydraulic cylinders :-

It is a device which converts fluid power into linear mechanical force & motion is generally in linear direction and we can use this motion with force for carrying out operations like pushing & pulling.

classifications :-

- A. Single acting single piston rod cylinder.
- B. Double acting single piston rod cylinder.
- C. Double acting double piston rod cylinder.
- D. Tandem cylinder.
- E. Telescopic cylinder.

2. Rotary Actuators or Hydraulic Motors :-

Hydraulic motors convert hydraulic energy into rotary mechanical energy used in many industrial applications. In hydraulic motors, the rotating element like vanes, gear, pistons are pushed by pressurized oil which results into continuous rotary motion of shaft.

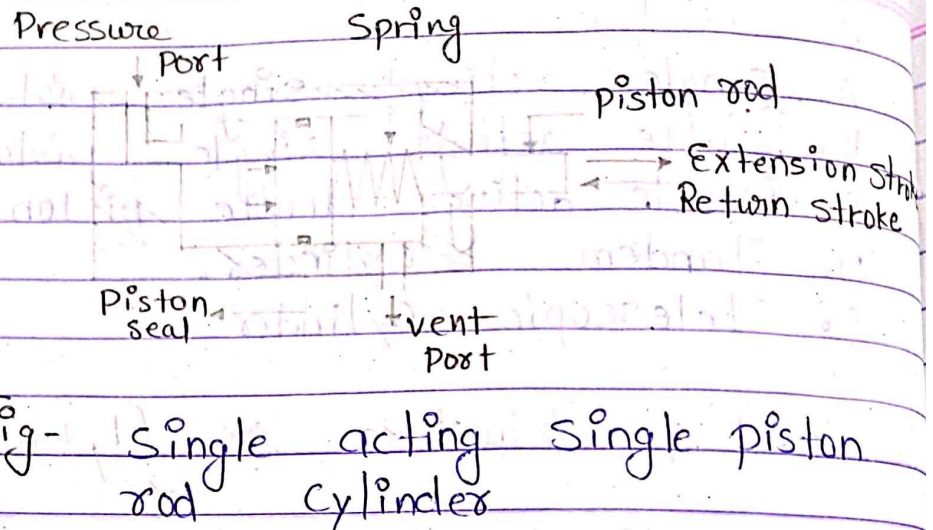
classifications :-

- A. Gear Motor, B. Vane Motor, C. Swash plate piston motor
- D. Bent axis piston motor, E. Radial piston motor.

1. Single acting single piston rod cylinder :-

* Construction :- It consists of a piston inside a cylindrical housing.

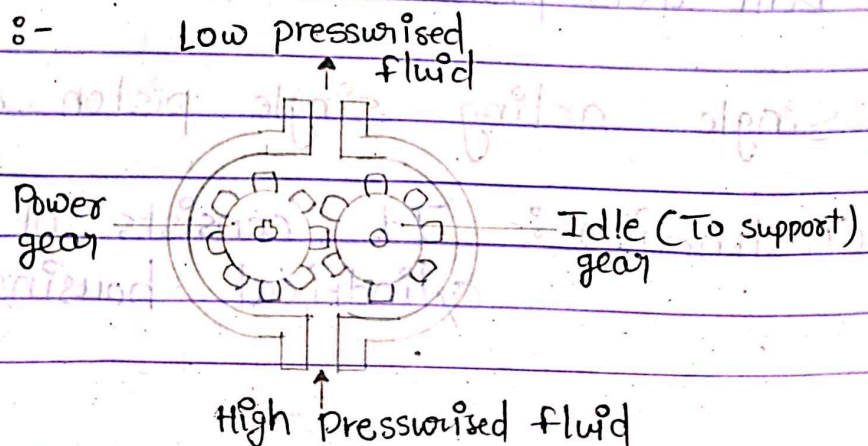
One end of the piston is attached with a piston rod and which can reciprocate at the opposite ends.



There is a pressure port and vent port for entrance and exit of oil or fluid.

* Working :- As soon as the hydraulic pressure increases at one face of the piston, it produces force in linear direction. enhance the extension stroke takes place. The return of piston is done by either by gravity or by spring.

A. Gear Motor :-



* Construction - It has two gears one gear is keyed to an output shaft while the other is simply an idle gear and the power gear is connected to the output shaft.

* Working - Pressurised oil is sent to the inlet port of the motor pressure is applied to the gear teeth causing the gears & output shaft to rotate the pressure builds until enough torque is generated to rotate the output shaft against the load. A gear motor develops torque due to hydraulic pressure acting against the area of one tooth. There are two teeth trying to move the ~~rotator~~ in proper direction, while one net tooth at the centre tries to move it in the opposite direction. Normally limited to one fifty bar operating pressure and 2500 r.p.m operating speed.

→ Control valve :- Control valves are the devices which are used to regulate and control the flow and pressure in any assigned manner are called control valves. In order to control the hydraulic outputs different types of control valves are required.

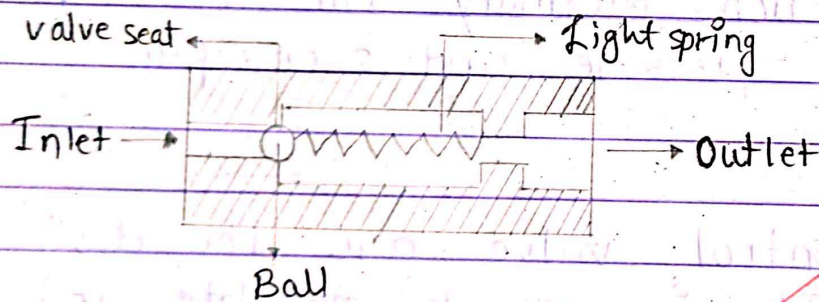
In other words - we can also say that Control Valve is nothing but a device which is necessary to control the oil energy.

→ Classifications - There are basically three types of valve employed in hydraulic system.

1. Direction control valve, (DCV)
2. Pressure control valve, (PCV)
3. Flow control valve, (FCV)

Direction control valve

→ (a) check valve :-



Sym →

Figure - Ball type check valve

The simplest DCV is a check valve. The check valve allows flow in one direction but blocks the flow in opposite direction. It is two way valve because it contains two ports.

* $F = kx$

Spring constant $k = \frac{F}{\Delta x \rightarrow \text{Deflection in spring}}$

A Light spring holds the ball against the valve seat.

Flow coming into the inlet pushes the ball off the seat against the light force of the spring and continuous to the outlet. A very low pressure is required to hold the valve open in this direction. If the flow tries to enter from the opposite direction the pressure pushes the ball against the seat and the flow can't pass through.

Exa - Tyre, Football, L.P.G. Cylinder.

(b) 2/2 Direction control valve -

Symbol

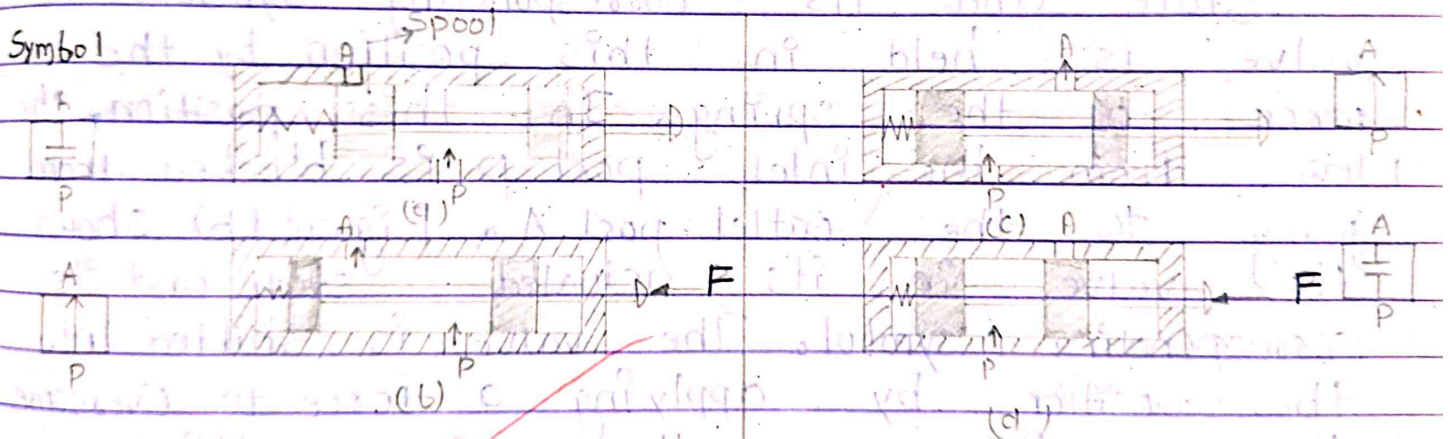


Fig - 2/2 normally closed DVC Fig - 2/2 normally Open DCV
 Port $\leftarrow$ $\rightarrow$ position

Normally closed -

Above figure shows a two-way two-position (normally closed) of spool type. A spool type valve consists of a cylindrical spool that slides back and forth inside the valve body to connect or block flow b/w the ports. The larger diameter portion of the spool land blocks flow by covering the port. This particular valve has two ports labeled P and A. P is connected to the pump line and A is connected to the outlet to the system. Figure (a) shows the valve in its normal state and its corresponding symbol. The valve is held in this position by the force of the spring. In this position, the flow from the inlet port P is blocked from going to the outlet port A. Figure (b) shows the valve in its actuated state and its corresponding symbol. The valve is shifted into this position by applying a force to overcome the resistance of the spring. In this position, the flow is allowed to go to the outlet port.

Normally Opened -

Figure shows a two-way, two-position normally open DCV. The spring holds the valve in a position in which ports P and A are connected as shown in figure (a). When the valve is actuated, the flow is blocked from going to A as shown in figure (b).

(c) 3/2 Directional control valve -

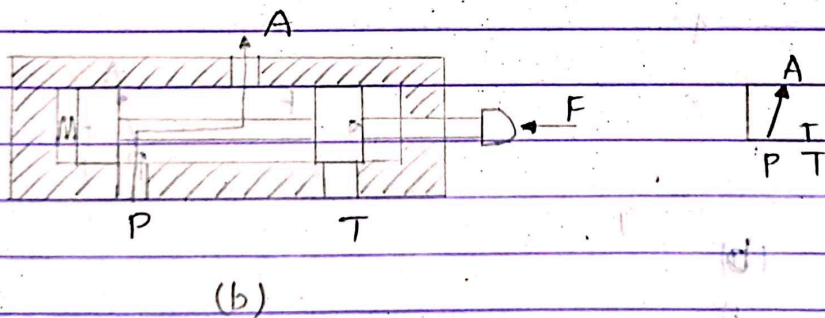
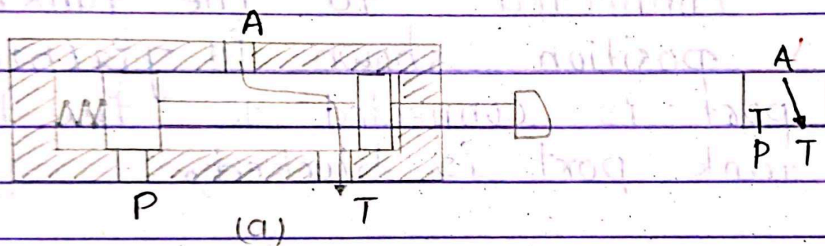


Figure - 3/2 - DCV (normally closed)

Three way valve either block or allow flow from an inlet to an outlet.

They also allow the outlet to flow back to the tank when the pump is blocked, while a two-way valve does not. A three-way valve has 3 ports, namely, a pressure inlet (P), an outlet to the system (A) and a return to the tank (T). Figure shows the operation of a $3/2$ -way valve normally closed. In its normal position, the valve is held in position by a spring as shown in figure. In the normal position, the pressure port P is blocked and outlet A is connected to the tank. In the actuated position shown in fig (b), the pressure port is connected to the tank (pump) and the tank port is blocked.

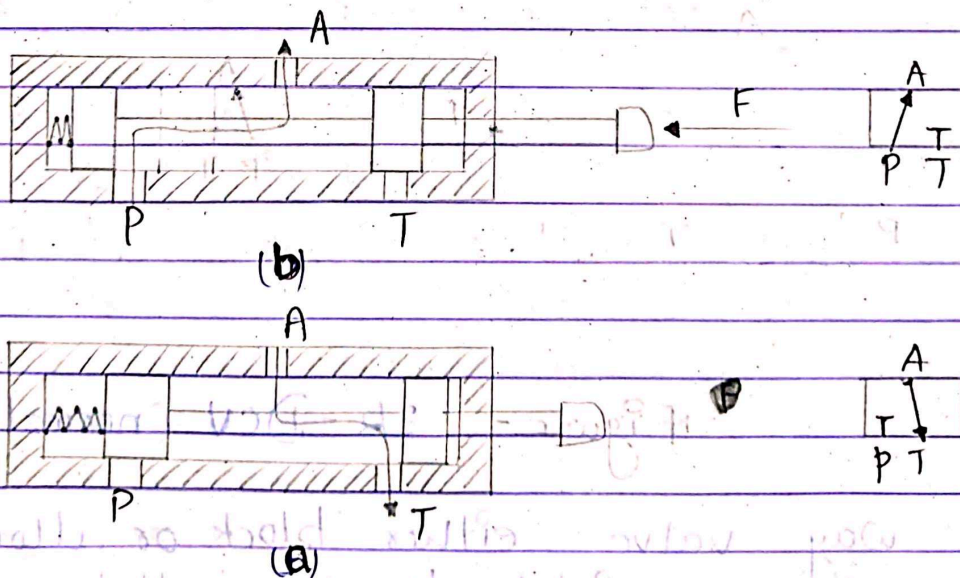


Figure- $3/2$ - Normally opened DCV

Above figure shows a 3-way, 3-position DCV (normally opened) with push button actuation and spring return. In the normal position, shown in figure (a), the valve sends pressure to the outlet and block the tank port in the normal position. In the actuated position, the pressure port is blocked and the outlet is vented to the tank.

(d) $4/2$ Direction Control valve :-

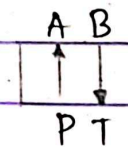
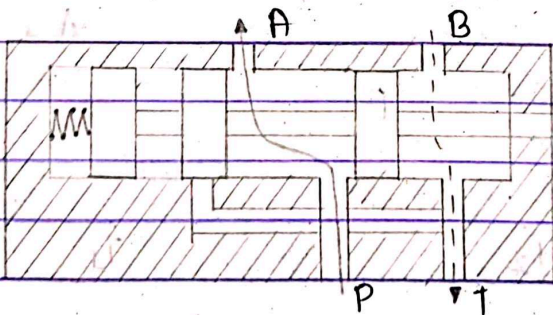
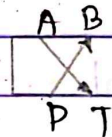
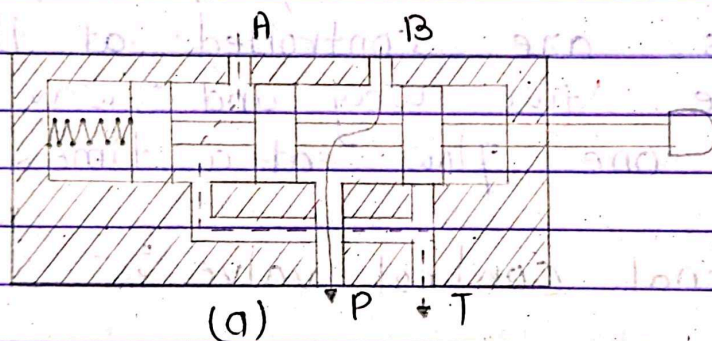
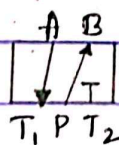
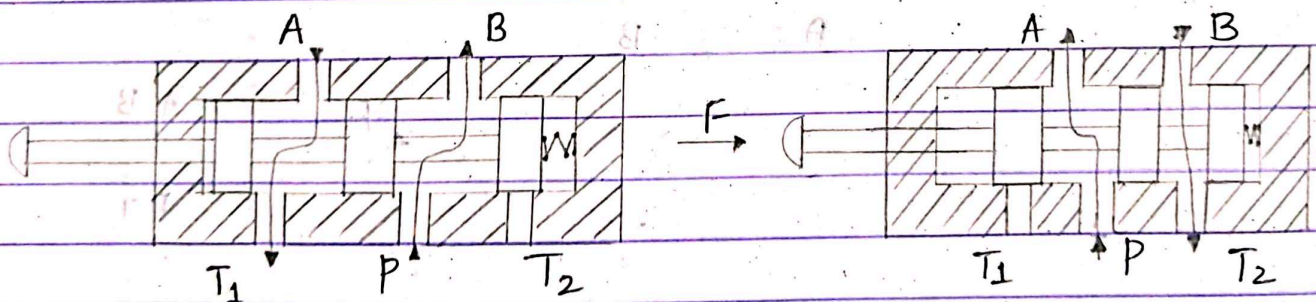


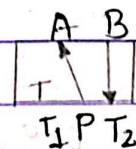
Figure - $4/2$ - DCV

Four-way DCVs are capable of controlling double-acting cylinders and bidirectional motors. Figure shows the operation of typical 4/2 DCV. A four-way has four ports labeled P, T, A and B. P is the pressure inlet and T is the return to the tank; A & B are outlets to the system. In the normal position, pump flow is sent to outlet B. Outlet A is connected to the tank. In the actuated position, the pump flow is sent to port A and port B connected to Tank T. In four-way DCVs, two flows of the fluids are controlled at the same time, while two way and 3-way DCVs control only one flow at a time.

(e) 5/2 Directional control valve :-



(b)



(a)

→ For acting Double Acting cylinder, we can use 5/2 Dcv.

→ 5/2 Dcv has two positions of its spool.

→ 5/2 Dcv has 5 ports namely inlet port "P", cylinder port "A" and cylinder port "B" tank ports "T₁" & "T₂".

→ The figure shows spring return type sliding spool valve. It has a spring-loaded spool inside the valve body. It is palm button operated spring return type of valve.

→ In 1st position of spool of 5/2 Dcv, oil under pressure flows from P to A and B to T₂. Hence the piston of Double acting cylinder extends.

→ In second position spool of 5/2 Dcv, oil under pressure flows from P to B and A to T₁. Hence the piston of DAC retracts.

(f) 4/3 - Directional control valve :-

→ This valve is used to operate DAC and bidirectional motor.

→ It has four ports, namely pump port "P", cylinder port "A", cylinder port "B" and Tank port "T".

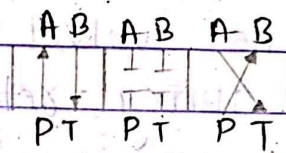
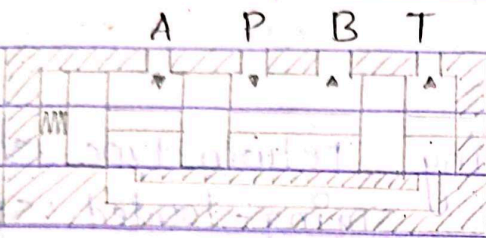
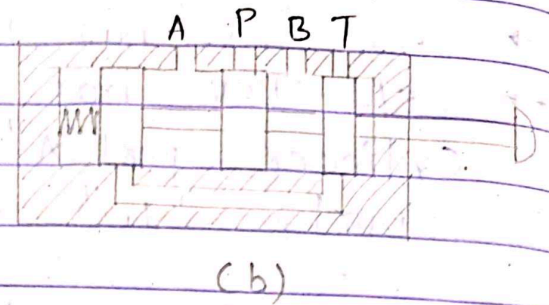
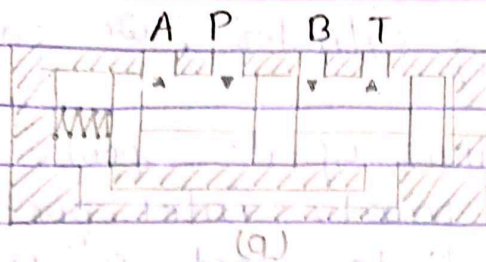


Figure - 4/3 - DCV

- It has 3 positions of its spool.
- In 1st position of spool position as shown in figure a, there is connection from P to A and B to T. working fluid flows to cap end port of cylinder, and comes out from rod end port. Hence the DAC extends.
- In 2nd position of spool position as shown in figure c, there is connection from P to B and A to T, working fluid flows to rod end port of cylinder, and comes out from cap end port. Hence the DAC is retracts.

→ In middle position of spool as shown in figure b, all ports are closed, and hence the actuator stops. This is closed centre mid position.

(g) 5/3 - (1) Directional control valve :-

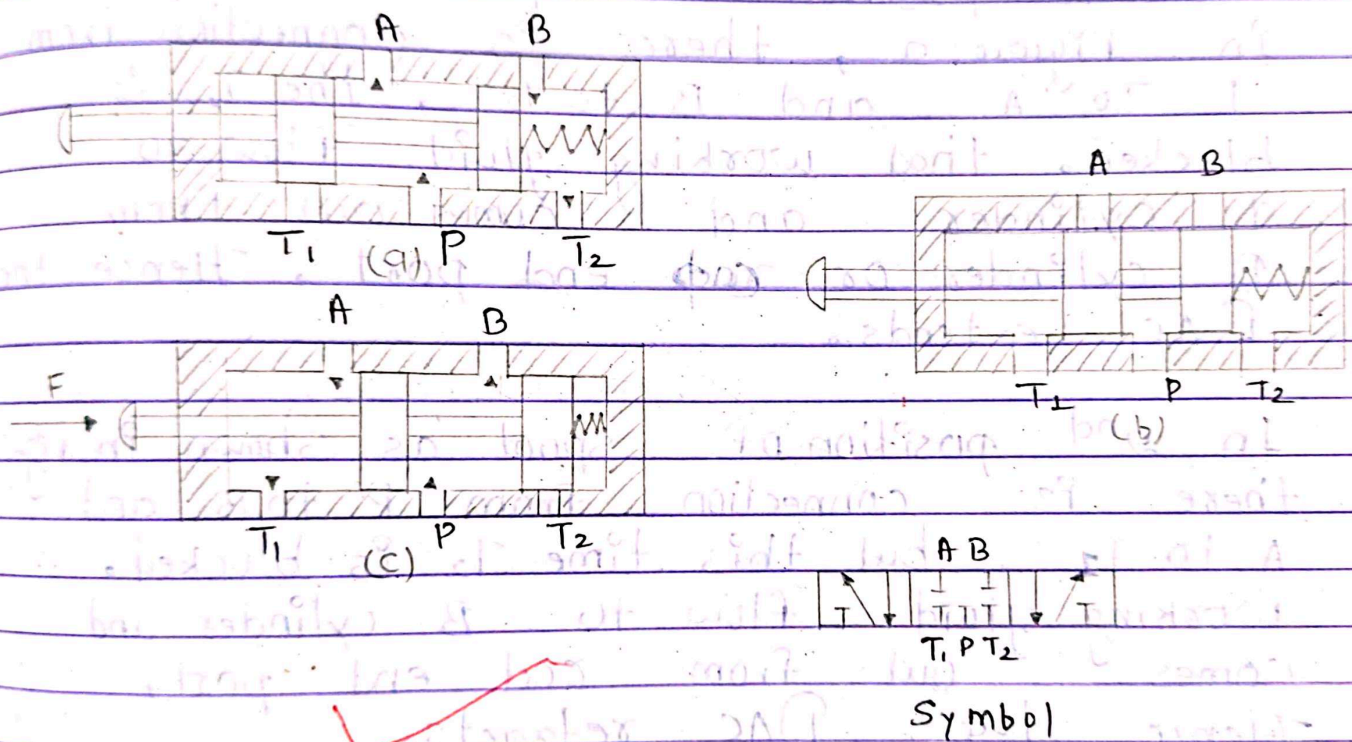


Figure - 5/3 - DCV

→ For acting Double acting cylinder, we can also use DCV 5/3.

→ 5/3 Dcv has three positions of its spool.

→ 5/3 Dcv has 5 parts namely inlet port or pump house "P", cylinder ports "A" & "B", and tank ports "T₁" & "T₂".

→ In first position of spool as shown in figure a, there is connection from P to A and B to T₂, the T₁ is blocked. that working fluid flow to A cylinder and comes out from B cylinder or ~~rod~~ end port, Hence the DAC extends.

→ In 2nd position of spool as shown in fig. c, there is connection from P to B and A to T₁, but this time T₂ is blocked. working fluid flow to B cylinder and comes out from rod end port, Hence the DAC retracts.

→ In middle position of spool as shown in figure b, all ports are closed, and the actuator is stop. This is Centre mid-position.

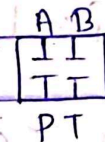
→ Standard Centre Position :-

S.No - Name - Symbol

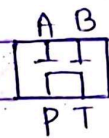
1. - Open centre -



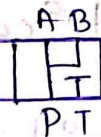
2. - Closed centre -



3. - Tandem centre -



4. - Regenerative centre -



5. - Float centre -



→ Methods of Actuation :-

1. Manual methods:-

A. Detent type -

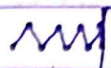


B. Hand lever Operated -

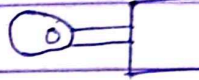


C. Palm Button operated - 

D. Foot Pedal operated - 

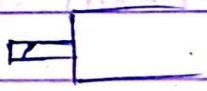
E. Spring Returned type - 

2. Mechanical Type :-

A. Roller (cam) Operated - 

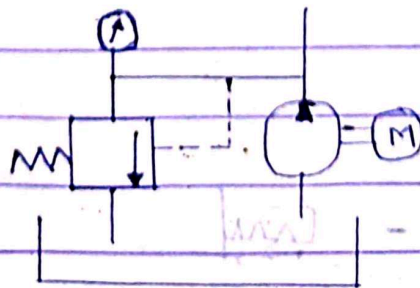
B. Pilot Operated - 

3. Electrical Type :-

A. Solenoid Operated - 

4. Hydro-electric Type :-

A. Hydraulic power pack



→ Pressure Control valve :-

1. Pressure Relief valve :- It is the most common pressure control valves used in hydraulic system.

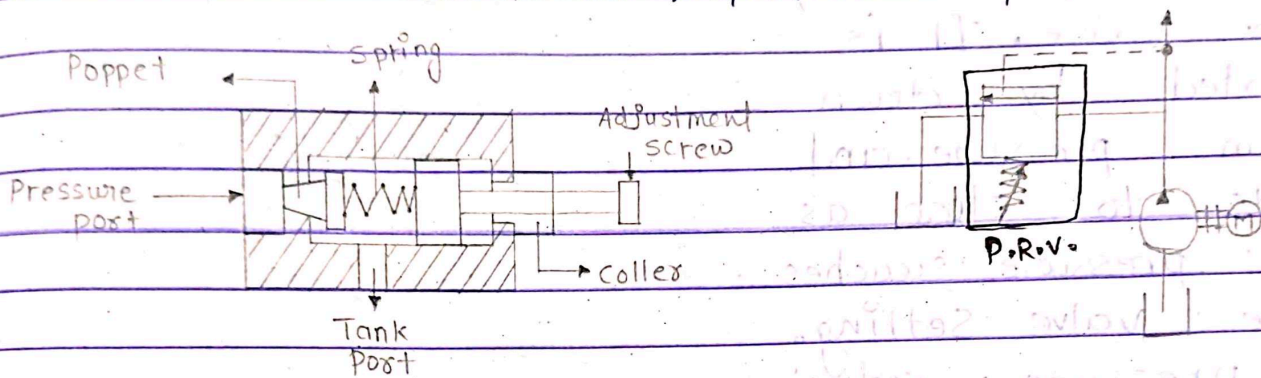


Figure - Pressure Relief valve

It is a normally closed valve whose function is to limit the pressure to a specified max^m value by diverting pump flow back to the tank.

A poppet is held seated in side the valve by a heavy spring. When the system pressure reaches a high enough value, the poppet is forced back to its seat. This permits flow through the outlet to the tank as long as this high pressure level is maintained. Note the external adjusting screw which varies spring force and thus the pressure at which the valve begins to open.

2. Pressure Reducing Valve :- This type of valve is used to maintain reduced pressure in a specified location of hydraulic systems.

It is a normally open valve. It is actuated by downstream pressure and tends to close as this pressure reaches the valve setting.

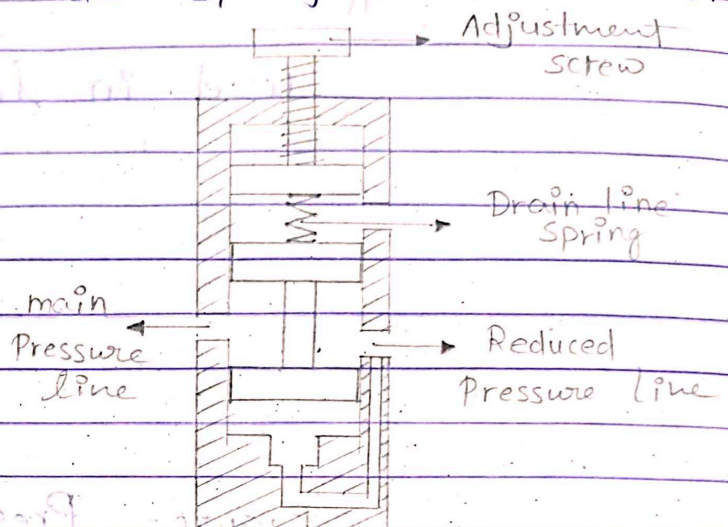


Figure - Pressure Reducing Valve

A pressure-reducing valve uses a spring-loaded spool to control the downstream pressure. If the downstream pressure is below the valve setting, the fluid flows freely from the inlet to the outlet. There is an internal passage way from the outlet which transmits outlet pressure to the spool end.

3. Unloading Valve :- It has two parts. One is connected to the tank and another is connected to the pump.

Adjustable screw

Inlet from pump

Pilot Pressure

Spring

Outlet to reservoir

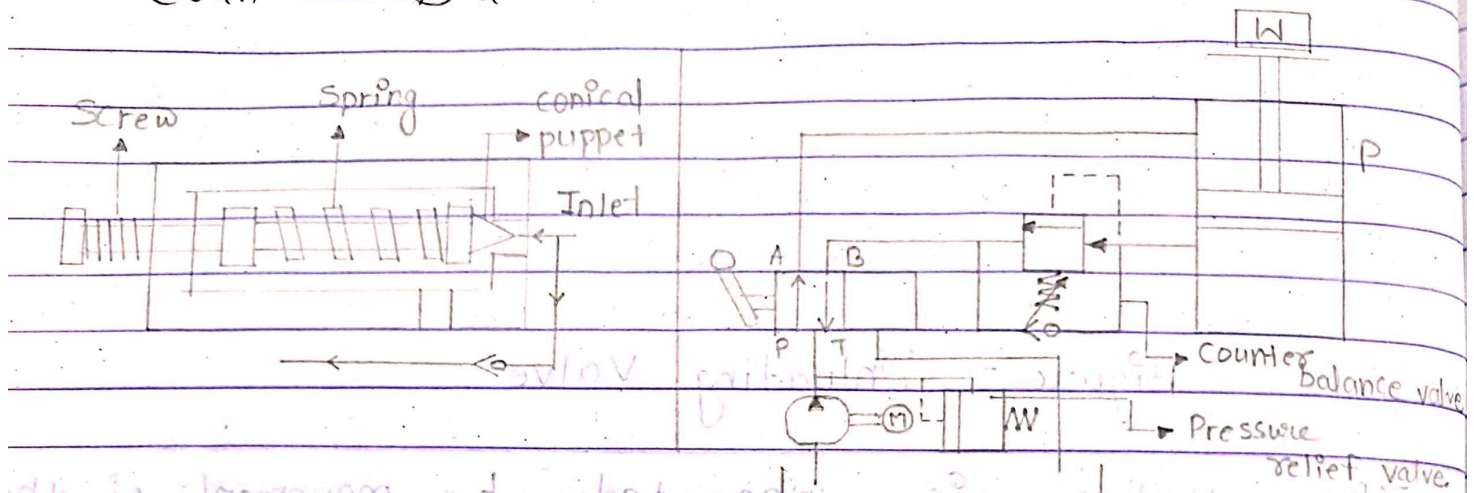
Figure - Unloading Valve

The valve is operated by movement of the spool. Normally the valve is closed and tank port is also closed. It works on the principle as DCV delivers hydraulic fluid to the tank when sufficient pilot pressure is applied to move the spool.

The pilot pressure maintains a static pressure to hold the valve open as the pressure is needed in the hydraulic circuit. The pilot pressure is relaxed and spool moves towards right side.

The unloading valve reduces the heat built-up due to fluid discharge at a preset pressure valve.

4th Counter Balance valve :-



Hydraulic circuit

Figure - Counter Balance valve

Counter balance valve is a normally closed valve, which are used to maintain a back pressure on a vertical cylinder to prevent it galling due to gravity. They are used to prevent a load from accelerating uncontrollably. This situation can occur in vertical cylinder in which the load is weight. This can damage the load or even the cylinder itself, when the load is stopped quickly at the end of travel.

5. Sequence Valve :-

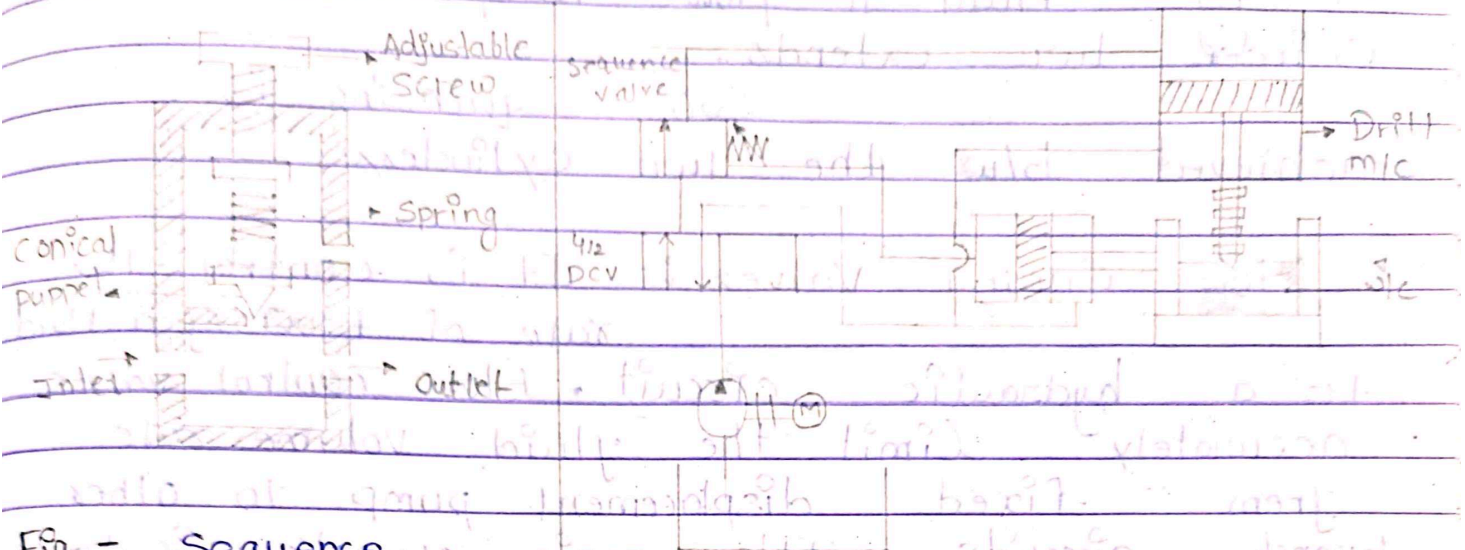


Fig - Sequence valve

A sequence valve is used to perform two operations in sequence one after the other.

For example - 1st cylinder one will extend and after that cylinder two will extend.

It has one inlet port and two outlet ports. It has an adjustable screw a spring and a conical puppet which are mounted inside the valve body as shown in figure. When working fluid is supplied to inlet port of a sequence valve it flows directly to outlet port one, hence 1st cylinder extends by completion of extension of 1st cylinder pressure in the line increases and puppet of sequence valve

lifts off from its seat and allows working fluid to flow to port two, hence cylinder two extends.

So sequencing is achieved b/w the two cylinders.

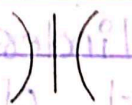
→ Flow Control Valves :- It is control the rate of flow of a fluid to a hydraulic circuit. Flow control valves accurately limit the fluid volume rate from fixed displacement pump to other branch circuits. It's main function is to provide velocity control of linear actuators and speed control of rotary actuators.

Use - 1. To varies the speed of spindle in lathe.

Functions of FCV :-

1. Regulate the speed of linear & rotary actuators.
2. Regulate the power available to the circuit.
3. Proportionally divide the pump flow to various branches of circuit.

Symbol of FCV :-



Simple FCV



adjustable screw
FCV

1. Non-Compensated Fcv :-

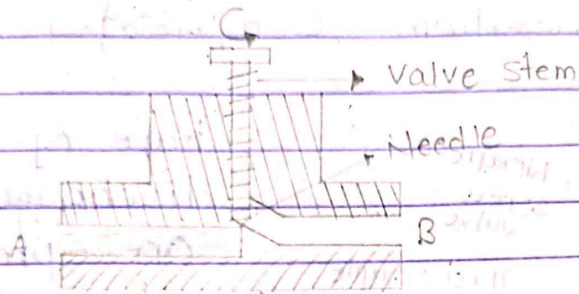


Fig :- Non-compensated Fcv

constant if the pressure drop across it remains the same. In other words the rate of flow through an orifice depends on the pressure drop across it.

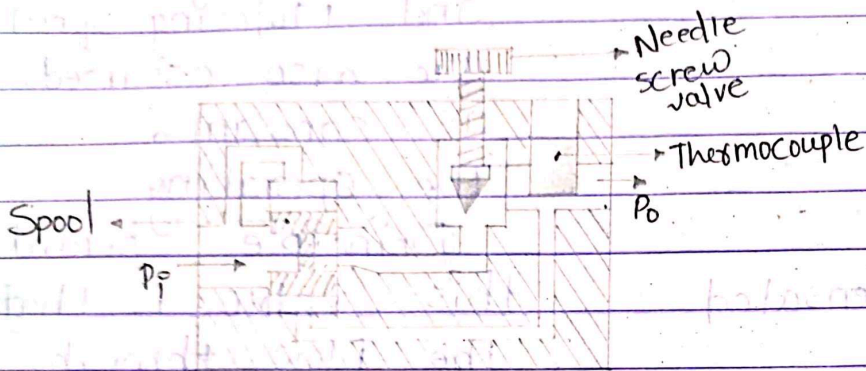
It consists of a adjustable Needle screw inside a tube like structure. Which is used as a adjustable orifice that can reduce or increase the flow in a circuit by turning the adjustable screw.

Needle valve behave as an orifice which provide constant flow for a particular needle valve position.

It is used when the system pressure is relatively constant and Motoring speed are also assumed as constant.

The operating Principle behind this valve is that the flow through an orifice remains

2. Pressure & Temperature Compensated FCV:-



Rate of flow or discharge depends on pressure & temperature of fluid. Hence any change in rate of flow which happens due to

pressure & temperature should be corrected in order to

maintain constant rate of flow as per needle screw valve setting.

(Pressure)
Working :- A. Temperature compensation :-

If inlet pressure P_i increases then the rate of flow will increase, to compensate this inlet pressure acts on the spool from the top and the spool moves down. Thus the area of flow reduces and constant discharge is achieved.

If Outlet pressure P_o increases then rate of flow will decrease, to compensate this

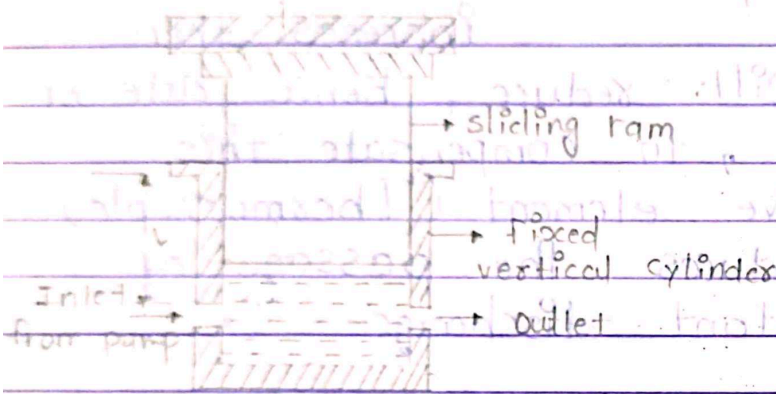
Outlet pressure acts on the spool from the bottom and the spool moves up. Thus the area of flow increases and discharge remains constant.

B. Temperature compensation :- If temp. of oil increases then its viscosity will reduce; hence rate of flow will increase, to compensate this temperature sensitive element (Thermocouple) expands and reduces the passage of fluid. Hence constant discharge is achieved.

If temp. of fluid decreases then its viscosity will increase and hence rate of flow will decrease, to compensate this thermocouple shrinks to its normal size and hence increases the passage for fluid, and hence constant discharge is achieved.

► Accumulator :-

→ Hydraulic Accumulator :- It is a device used for storing the energy of a fluid in the form of pressure energy which may be supplied for any sudden requirement. In case of a hydraulic lift or hydraulic crane a large amount of energy is required when lift or crane is moving upward. This energy is supplied from hydraulic



accumulator, but the lift is moving in downward direction. No large external energy is required and that time energy from the pump stored in the accumulator.

Working :- Figure shows a hydraulic accumulator which consists of a fixed vertical cylinder containing a sliding ram. A heavy weight is placed on the ram. The inlet of the cylinder is connected to the pump, which continuously supplies water under pressure to the cylinder. The outlet of the cylinder is connected to the machine.

The ram is at the lowermost position in the beginning. The pump supplies water under pressure continuously. If the water under pressure is not required by the machine (lift or crane), the water under pressure will be stored in the cylinder.

This will raise the ram on which a heavy weight is placed. When the ram is at the uppermost position, the cylinder is full of water and accumulator has stored the max^m amount of pressure energy.

When the machine (crane) requires a large amount of energy, the hydraulic accumulator will supply this energy and ram will move in the downward direction.

→ Capacity of Hydraulic Accumulator :-

It is defined as the max^m amount of hydraulic energy stored in the accumulator.

$$\text{Work done} = \text{Force} \times \text{displacement}$$

$$= P \times A \times L$$

$$W = P \times \text{volume of accumulator.}$$

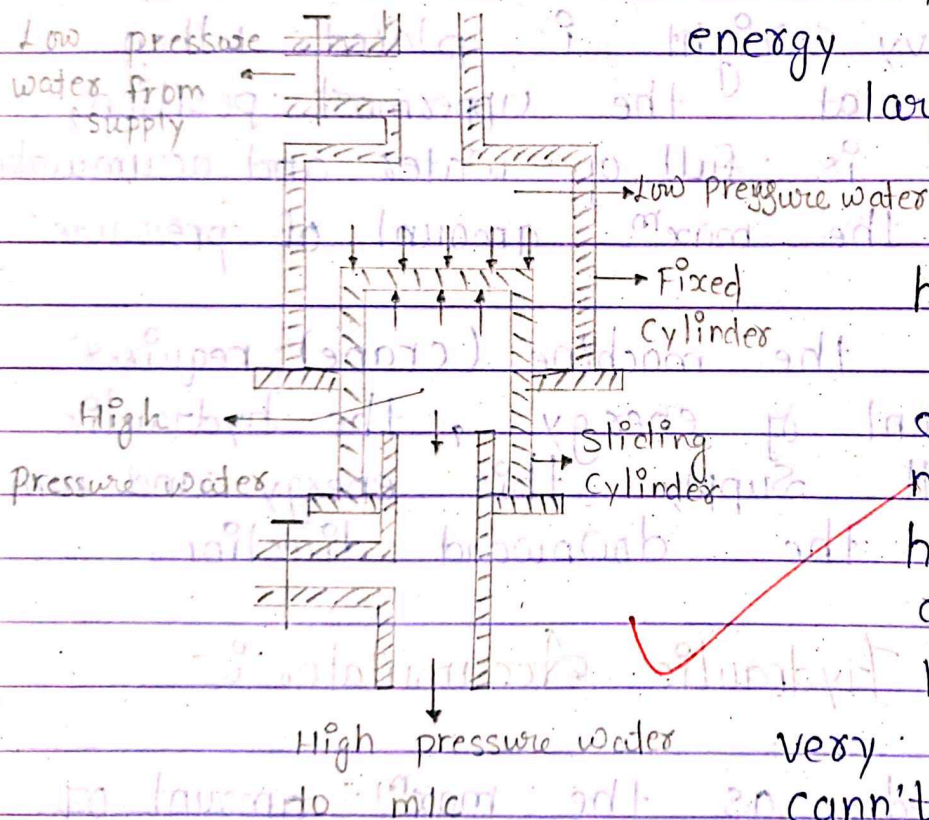
Here, P = Pressure Intensity

A = Area of ram

L = Lift of ram

► INTENSIFIER :-

→ Hydraulic Intensifier :- The device, which is used to increase the intensity of pressure of water by means of hydraulic energy available from a large amount of water at a low pressure, is called hydraulic intensifier.



Such a device is needed when the hydraulic m/c such as hydraulic press requires water at very high pressure which can't be obtained from the main supply

Figure directly.

Working :- A hydraulic intensifier consists of fixed ram through which the water, under a high pressure, flows to the machine.

A hollow inverted sliding cylinder, containing water under high pressure, is mounted over the fixed ram. The inverted sliding cylinder is surrounded by another fixed inverted cylinder which contains water from the main supply at a low pressure as shown in figure.

A large quantity of water at low pressure from supply enters the inverted fixed cylinder. The weight of this water pressure the sliding cylinder in the downward direction. The water in the sliding cylinder gets compressed due to the downward movement of the sliding cylinder and its pressure is thus increased. The high pressure water is forced out of the sliding cylinder through the fixed ram, to the machine as shown in figure.

► Seal And Their Functions :-

Seals are used in hydraulic systems to prevent excessive internal and external leakage and to keep out contamination.

Functions are

- Prevent leakage - both internal and external.
- Prevent the dust & other particles entering into the system.
- Maintain pressure.
- Enhance the service life & reliability of the hydraulic system.

Classification :-

1. Hydraulic seals can be classified according to the method of sealing as, -

- a. Positive sealing.
- b. Non-positive sealing.

2. Hydraulic seals can be classified according to the relative motion exist between the seals and other parts as, -

- a. Static seal
- b. Dynamic seal

3. Hydraulic seals may be classified according to geometrical cross section as,

- a. O-Ring seal
- b. V-Ring & U-ring seal
- c. T-ring seal
- d. Piston cup packings
- e. Piston rings
- f. Wiper rings

A positive seal prevents even a minute amount of oil from getting past. Positive seals do not allow any leakage whatsoever. A non-positive seal allow a small amount of internal leakage, such as the clearance of the piston to provide a lubrication film.

► Sealing materials :- Natural rubber is rarely used as a seal material because it swells and deteriorates with time in the presence of oil. In contrast, synthetic rubber materials are compatible with most oils. The most common types of materials used for seals are leather, Buna-N, silicone, neoprene, tetrafluoroethylene, viton and of course, materials.

► Functions of Reservoir system :-

- To provide a chamber in which any change in volume of fluid in the hydraulic circuit can be accommodated. When the cylinder extend there is an increased volume of fluid in the circuit and consequently there is a decrease in the reservoir level.
- It provide a filling point for the system.
- The reservoir serves as a storage space for the hydraulic fluid used in the system.
- The reservoir also uses as the location where the fluid is conditioned.
- To provide a volume of fluid which is relatively stationary to allow entrained air to separate out and heavy contaminants to settle. The reservoir is where sludge, water and metal chips settle.
- The reservoir is a place where the entrained air picked up by the oil is allowable to escape.
- The dissipation of heat is accomplished by a properly designed reservoir.

It provides a radiating and convective surface to allow the fluid to cool.

► Filter And classification :-

Filter is a device whose primary function is the retention, by some fine porous medium, of insoluble contaminants from the fluid.

Fluid flow has to follow a winding path and through the element. Filters are used to pick-up smaller contaminant particles because they are able to accumulate them better than a strainer.

→ Types

A) Filters may be classified according to the filtering methods as

1. Mechanical Filters
2. Absorption Filters
3. Adsorbent Filters

B) Filters may be classified according to the size of pores in the material as

1. Surface filters , 2. In depth filters.

c). Filters are classified according to the location of filters as

1. Intake or inline filter,
2. Pressure line filter,
3. Return line filter,

► Pipe :-

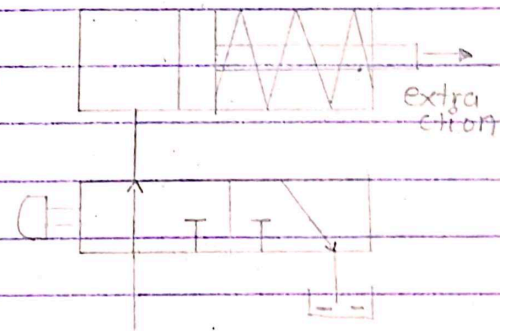
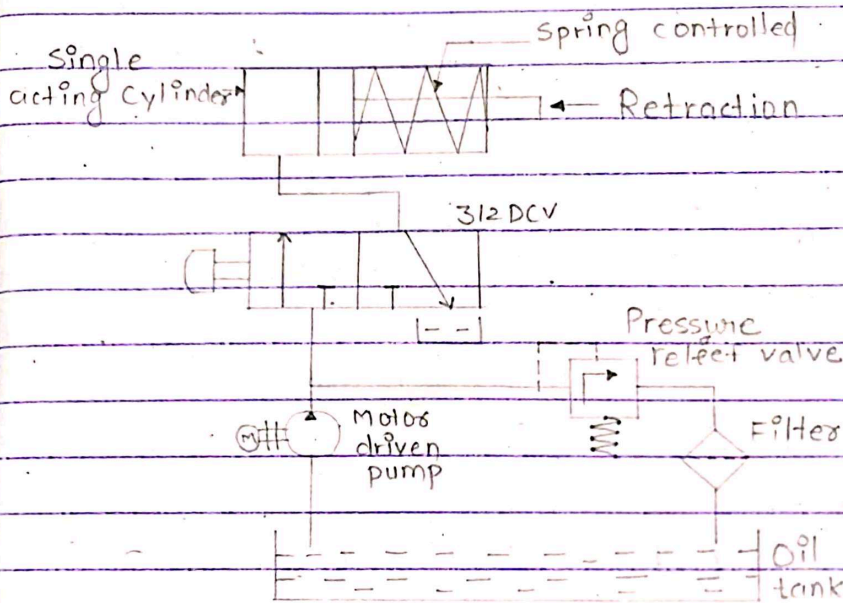
- A pipe can be defined as a functional connection for fluid flow in the fluid power system.
- In hydraulic system, iron pipes may be used for low to medium pressure range. But, heavy wall thickness, lack of annealing and inability to absorb high pressure are certain problems with iron pipes.
- Stainless steel pipes are used in application that require resistance to corrosion.
- The term pipes, tubes, and hoses are generally synonymous, each have their own specific characteristic for a specific applications.

► Hose :-

- A hydraulic hose is specifically designed to convey hydraulic fluid to or among hydraulic components, valves, actuators and tools.
- It is typically flexible, often reinforced and usually constructed with several layers of reinforcement.
- Since hydraulic systems frequently operate at high or very high pressure.
- A hydraulic hose is used anywhere in a hydraulic system requiring a flexible connection b/w two fluid ports.

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► Control of single acting cylinder :-



1. Non-actuated position

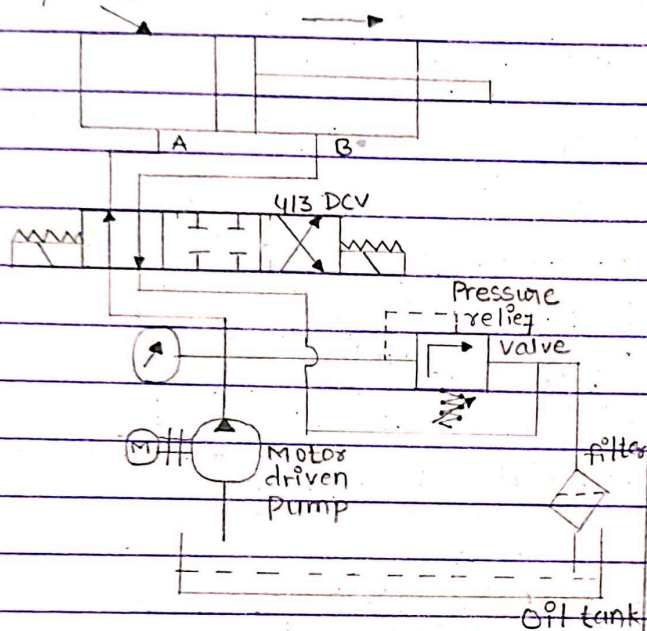
2. Actuated Position

This cylinder is controlled by 3/2 DCV.

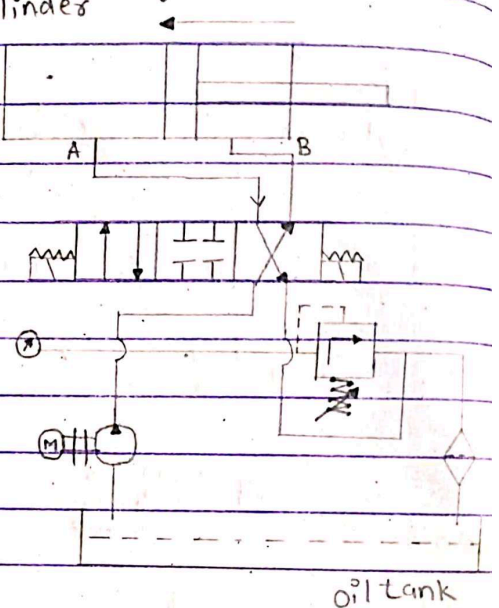
Control of Double acting cylinder :- Theory

Similar to 4/3 DCV

Double acting cylinder

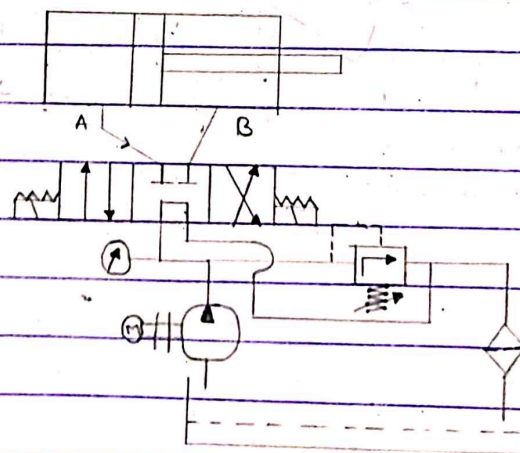


Double acting cylinder



1. Piston extending moving from left to right

2. Piston retracting moving from right to left



3. NO movement of piston (Tandem centre position)

► Speed Controlling Circuits :-

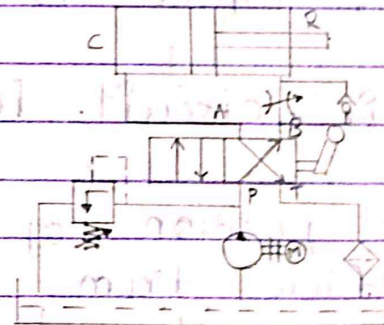
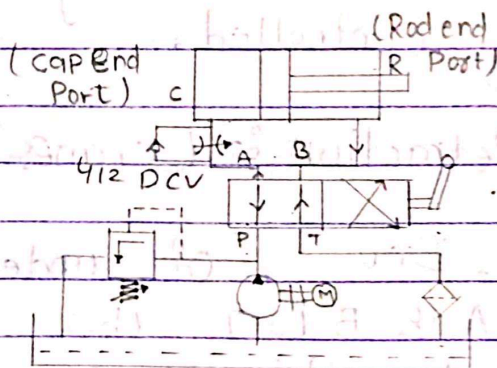
In hydraulic operation it is necessary to control the speed of actuator so as to control the force, power, timing and other factors of the operation. Actuator speed control is achieved by controlling the rate of flow into or out the cylinder.

Speed control by controlling the rate of flow into the cylinder, is called Meter-In-Control.

Speed control by controlling the rate of flow out of the cylinder, is called Meter-out-control.

1. Meter-In-circuit, 2. Meter-out-circuit, 3. Bleed-off-circuit.

1. Meter-In-circuit :- [Shaper Machine]



1. Meter-in-circuit
for extension

2. Meter-out-circuit
for Retraction

In this circuit the rate of flow of oil going into the cylinder is controlled by flow control valve. Fcv is placed at inlet of the cylinder cap end port (C) is inlet for extension and Rod end port (R) is inlet for Retraction.

→ Working:-

A. Meter-in-circuit for extension :- [shaper]

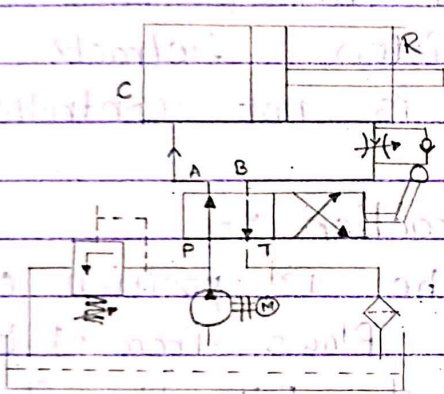
In first position of $4/3$ Dcv, oil under pressure flows from P to A & B to T. This flow is through fcv, the flow is controlled and hence piston extends slowly. In second position of $4/3$ Dcv, oil under pressure flows from P to B & A to T, this flow is through check valve. This is free flow hence the piston retracts at a higher speed, which is not controlled.

B. Meter-in-circuit for Retraction :- [cranes, Drilling]

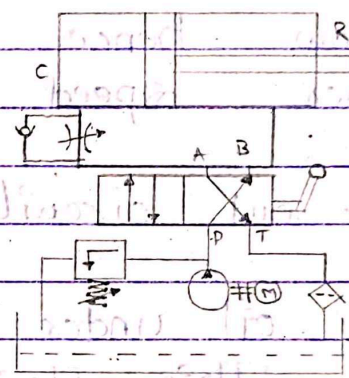
In first position of $4/3$ Dcv, oil under pressure flow from P to A & B to T this flow is through check valve, this is free flow. Hence the piston extends at higher speed which is not controlled.

In 2nd position of 4/3 Dcv, Oil under pressure flows from P to B & A to T. This flow is through control valve. the flow is controlled and hence piston retracts slowly.

2. Meter-out - circuit :-



A. Meter-out circuit for extension



B. Meter-out - circuit for Retraction

In meter out circuit the rate of flow of oil under pressure coming out of the cylinder controlled by flow control valve. FCV is placed at outlet of the cylinder.

A. Meter-out circuit for extension :-

In the 1st position of 4/2 Dcv oil under pressure flows from P to A & B to T. This flow is through Fcv the flow is controlled and hence piston extends slowly.

In 2nd position 4/2 Dcv oil under pressure flows from P to B & A to T. This flow is through check valve, this is free flow hence the piston retracts at a higher speed which is not controlled.

B. Meter-out circuit for Retraction :-

In the 1st position of 4/2 Dcv oil under pressure flows from P to B, A to T. This flow is through Fcv the flow is controlled and hence piston retracts slowly.

In the 2nd position 4/2 Dcv oil under pressure flows from P to A, B to T. This flow is through check valve, this is free flow hence the piston extends at a higher speed which is not controlled.

3. Bleed-off circuit :- In this type of circuit an additional by pass line is run through a flow control valve into the tank.

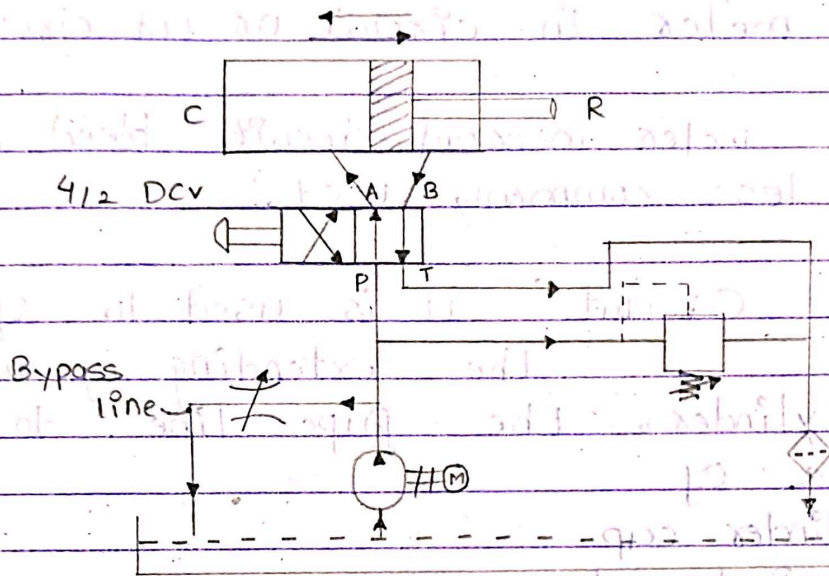


Figure - Bleed-off circuit

To slow down the actuator some of the flow is bleed off through Fcv, into the tank before it reaches the actuator. This reduces the flow into the actuator and hence reduces the speed of extension or retraction.

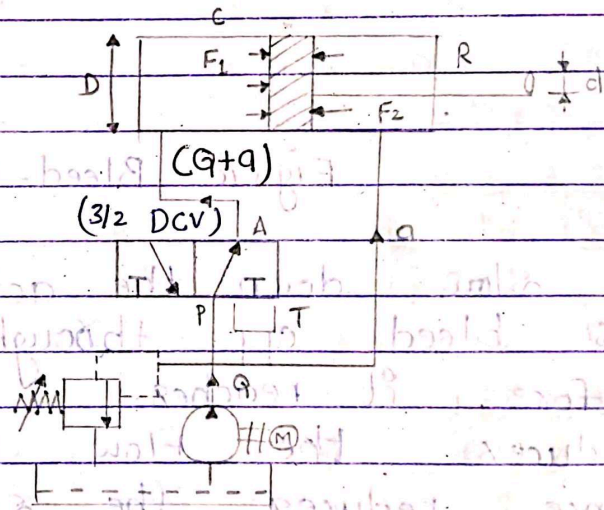
Applications :- 1. Broaching, 2. Milling, 3. Shaper, 4. Lathe, 5. Drilling, 6. Grinding

Note:- The main difference b/w a bleed-off-circuit meter-in or out-circuit is that in a bleed-off-circuit opening the FCV decreases the speed of actuator where as in the case of meter-in-circuit or out-circuit it is reverse.

Compare to meter-in or out-circuit bleed off circuit is less commonly used.

► Regenerative Circuit :- It is used to speed up the extending of double acting cylinder. The pipe line to both the ends of

hydraulic cylinder cap port (C) and Rod port (R) are connected before $3/2$ Dcv. during the extension stroke the speed of actuator is increases in the circuit.



In First position at $3/2$ Dcv :-

Figure - Circuit (Regenerative) by using $3/2$ Dcv

P is connected to both C and R and T is closed.

$$\begin{aligned}\text{Net Force} &= F_1 - F_2 \\ &= (P \times A) - [P(A-a)] \\ &= PA - PA + Pa\end{aligned}$$

$$\text{Net Force} = Pa$$

where, P = Pressure acting both side a piston.

A = Area of piston at cap end.

a = area of piston at rod end.

So this net forces is called regenerative extraction stroke.

due to the net forces piston extends $\neq \frac{(Q+q)}{A}$

velocity of piston cap end = $\frac{(Q+q)}{A}$

velocity of piston rod end = $\frac{q}{A-a}$

In Second Position: at $3/2$ DCV :-

This is normal retraction stroke oil flows from pump to R and C to T and P is closed.

During this stroke net forces = $[P \times (A-q)]$

at during the retraction stroke due to this force piston retracts. velocity of piston = $\frac{Q}{(A-a)}$

► Synchronizing Circuit :-

[1st cylinder → 2nd cylinder
Rod end → Rod end
Parallel] called

[1st Rod end → 2nd Cap end
called series]

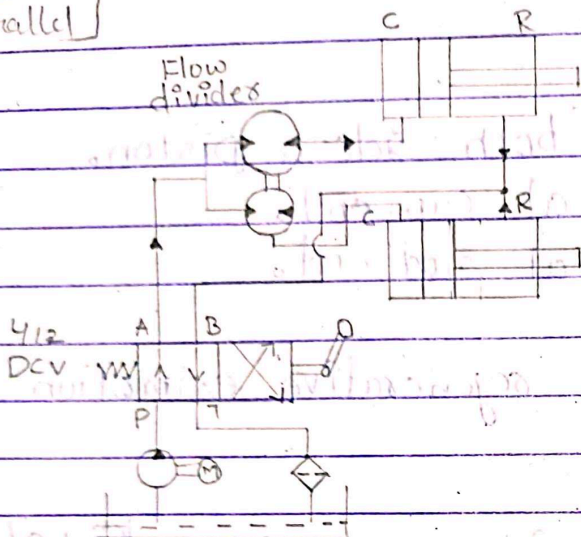


Figure - synchronizing circuit for cylinder in parallel

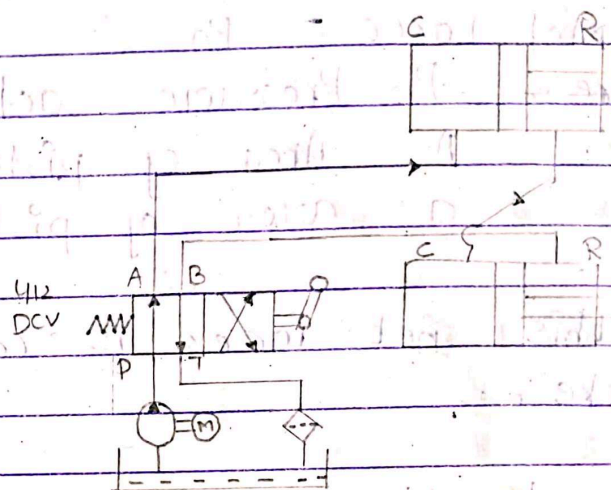


Fig - Synchronizing circuit for cylinder in series

Machines with multiple cylinder required that the cylinder stroke be perfectly synchronized for the machine to operate properly. In other words synchronizing circuits are used where motion of two or more cylinder required to be work simultaneously.

A. Synchronizing circuit for cylinder in parallel :-

In figure two cylinders are connected in parallel to a 4/2 DCV and 4/2 DCV is connected to flow divider.

Figure - Shapes Machine

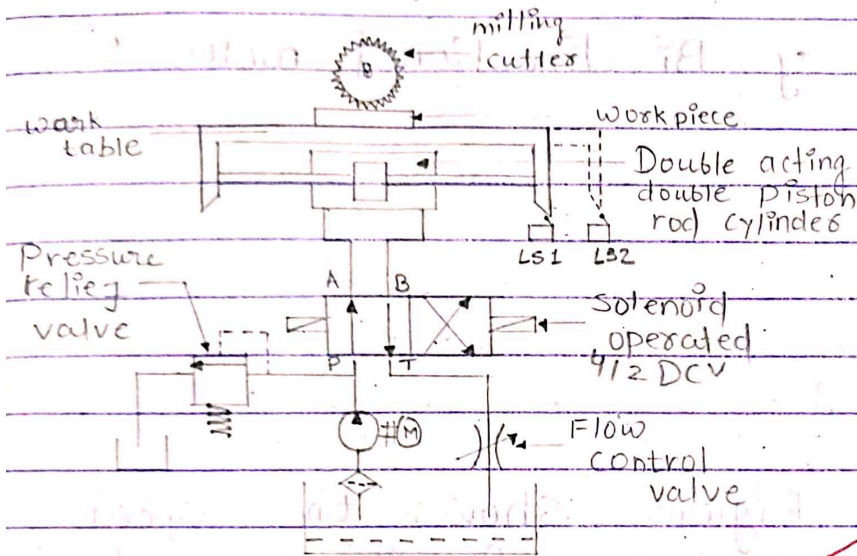
Hydraulic Shaper operated on the principle of meter-out-circuit, hence flow rate is controlled by flow control valve.

Flow control valve is placed between the outlet port and tank. When pump delivers the pressurized fluid into the hydraulic circuit it goes first into the Dcv and Direction control valve transfer the fluid into actuator. In actuator cylinder at outlet side there is flow control valve with check valve is present to control the speed of actuator. At the end of Ram an arm is attached with push rod of Dcv. While Ram travels Right to left or left to Right then by push rod of Dcv changes its position and fluid will flow alternatively into inlet and outlet port.

Tool is attached with Ram and tool also reciprocates with this mechanism and machining is performed by the shaper.

► Hydraulic circuit for milling machine :-

LS1 = Limiting switch 1
LS2 = Limiting switch 2



In hydraulic milling machine there is a simple mechanism used to move the work table. Machine table is connected with double acting double piston rod cylinder at both ends.

In this circuit limiting switch & 4/2 solenoid operated DCV is used.

Figure :- Milling machine

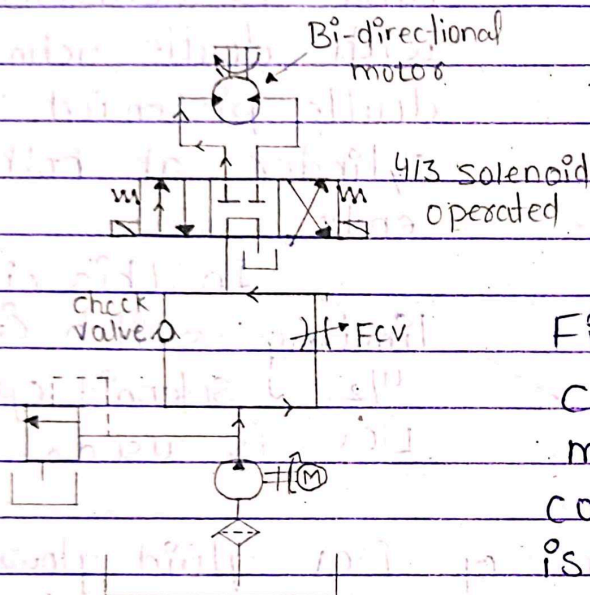
► Working :- In 1st position of DCV fluid flows from pump P to A and B to T. Port A is connected to extension stroke and port B is connected to tank Port. During extension stroke and return stroke limit switch is actuated. When work table touches the limiting switches it sends signal to DCV to change it's position. When Limiting switch - 1 is actuated, then 1st position of DCV is working and when Limit switch - 2



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is activated then 2nd position of Dcv is working. This motion is used move the table to & fro, then machining is done on the milling machine.

► Speed control of Bi-directional motors :-



○ = Uni-directional hydraulic motor

○ = Bi-directional hydraulic motor

Figure shows the speed control circuit of a hydraulic motor using a pressure-compensated FCV. The operation is as follows.

Figure

• In a Spring-Centered position of the tandem four-way valve, the motor is hydraulically blocked.

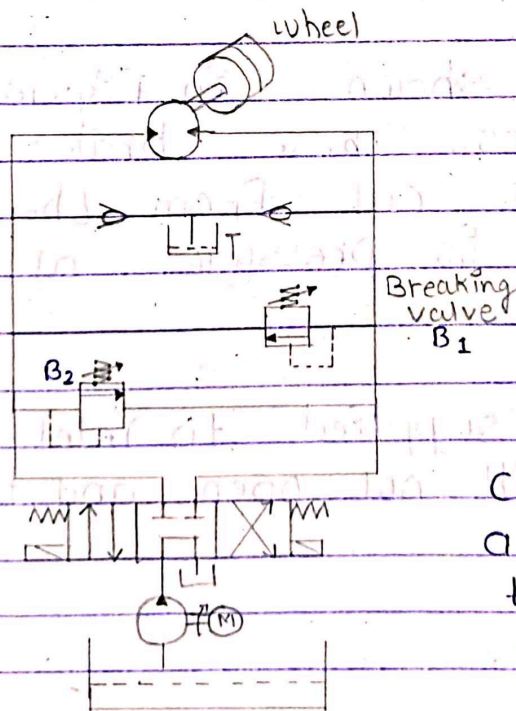
• When the valve is actuated to the left envelope, the motor rotates in one direction. Its speed can be varied by adjusting the throttle of the FCV. Thus, the speed can be

infinitely varied and the excess oil goes through the Pressure Regulating valve.

- When the valve is deactivated, the motor stops suddenly and becomes locked.
- When the right envelope is in operation, the motor turns in the opposite direction. The PRV provides overload protection if, for example, the motor experiences an excessive torque load.

► Braking and Replenishment of hydraulic motors :-

- As we know, when we keep the lever of 4/3 Dcv to mid-position, the motor will stop. But there are two issues.



Figure

1. Motor may over run due to over-running load and the load may fall.

2. Motor due to inertia, continues to rotate for a considerable amount of time before it comes to rest.

► To avoid this, brake valves B_1 and B_2 are used in the circuit.

► In first position of $4/3$ Dcv, oil flows from P to A and B to T, hence motor runs in forward direction.

► In Second position of $4/3$ Dcv, Oil flows from P to B and A to T, hence motor runs in reverse direction.

► In middle position of $4/3$ Dcv, all ports are blocked. If the motor is loaded with over running load and if brake valves are not used, then the load will fall.

► In the circuit shown in figure, there are two brake valves. These brake valve will allow oil to flow out from the motor if and only if there is pressure at the inlet of motor.

► If oil is not supplied to inlet of motor, then its outlet will not open, and the motor shaft is locked.

► Replenishing of hydraulic motor :-

When the brake is applied to motor then it continues to revolve due to inertia.

Due to this it starts to pump out the remaining fluid from the inlet circuit to outlet circuit and vacuum is created inside the motor and circuit.

Which leads to the pressure drop below vapour pressure of hydraulic fluid and hence cavitation starts.

To avoid cavitation replenishing valve supplies extra amount of fluid to the circuit and hence cavitation does not occur.

UNIT- 4.0

Elements of Pneumatic System

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- Pneumatic System :- Pneumatic system deals with the study of behavior and application of compressed air in daily life and manufacturing automation.

This system uses air as the medium and can be exhausted into the atmospheric after completion of the assigned work.

In pneumatic system compressed air or gases are converted into useful mechanical work, like operating the actuators (It may be linear & rotary).

- Application :-

1. Manufacturing Industry, drilling, Punching, clamping, riveting.
2. Automobile industry.
3. Glass industry.
4. Packaging, Filling, Stamping, embossing.


31/01/2022

► Air compressor :-

1. Reciprocating compressor :-

Piston type compressors are the oldest and most commonly used compressor in the pneumatic industry because of its flexibility, high pressure capability, ability of rapidly dissipate heat of compression and oil free.

► Construction :- Piston type of compressor consists of cylinder, cylinder head, and piston with piston rings, inlet and outlet spring loaded valves, connecting rod, crank, crankshaft & bearings.

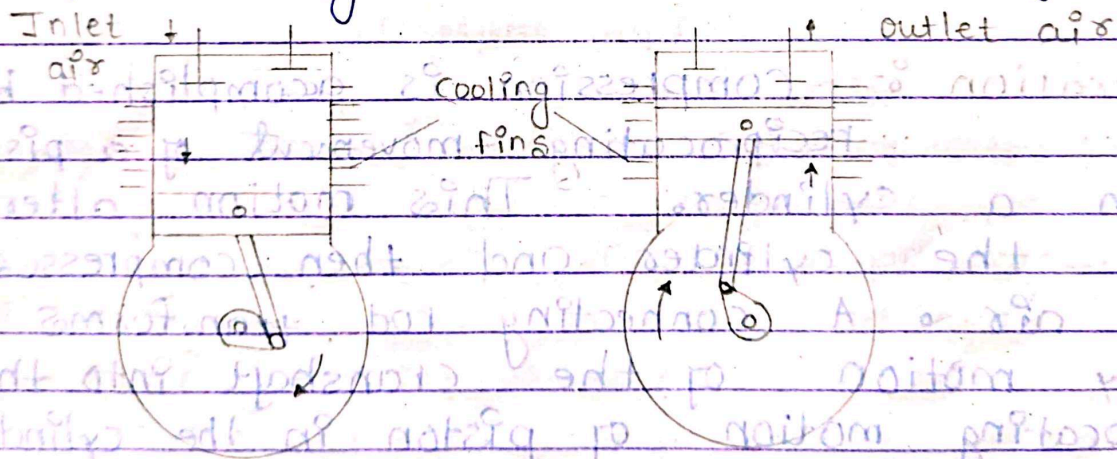
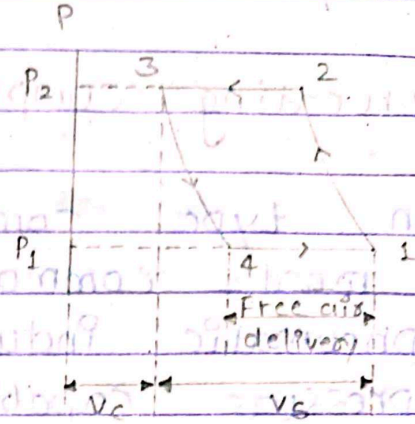
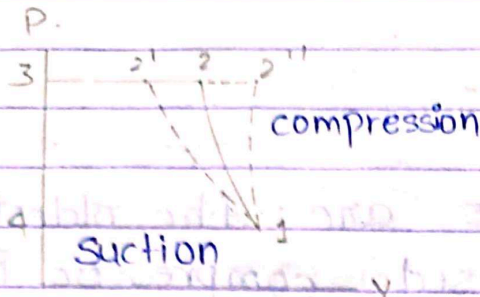
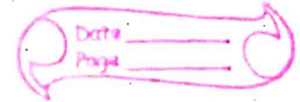


Figure :- Single cylinder compressor



1. P-v diagram without clearance
P-v

2. P-v diagram with clearance

1-2' = Isothermal

1-2'' = Isentropic

1-2 = Polytropic
($Pv^n = c$)

▷ Operation :- Compression is accomplished by the reciprocating movement of a piston within a cylinder. This motion alternately fills the cylinder and then compresses the air. A connecting rod transforms the rotary motion of the crankshaft into the reciprocating motion of piston in the cylinder. Depending on the application, the rotating crank is driven at constant speed by a suitable prime mover.

▷ Inlet stroke :- suction or inlet stroke begins with piston at top dead centre. During the downward stroke, piston motion reduces the pressure inside the cylinder below the atmospheric pressure. The inlet valve then opens against the pressure of its spring and allows air to flow into the cylinder. The air is drawn into the cylinder until the piston reaches to a max^m volume position (bottom dead centre). The discharge valve remains closed during this stroke.

▷ Outlet stroke :- During compression stroke piston moves in the opposite direction (BDC to TDC), decreasing the volume of air. As the piston starts moving upwards, the inlet valve is closed and pressure starts to increase continuously until the pressure inside the cylinder is above the pressure of the delivery side which is connected to the receiver.

Then the outlet valve opens and air is delivered during the remaining upward motion of the piston to the receiver.

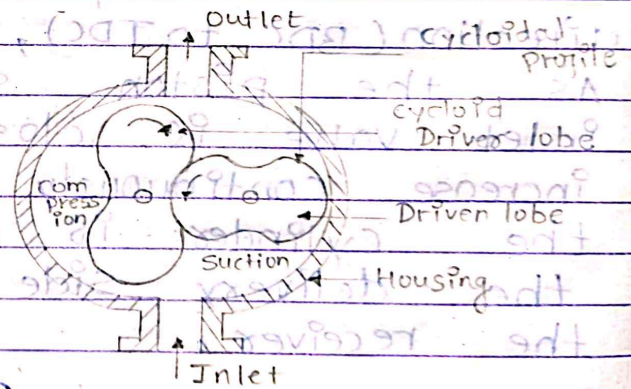
2. Rotary Compressor :-

- vane compressor, - Centrifugal compressor,
- screw compressor, - Root blower / Lobe compressor.

► Root Blower or Lobe Compressor :-

Rotary compressor is a type of gas compressor which uses rotary type positive displacement mechanism for compressing the gas. We are going to discuss the lobe type compressor as a rotary compressor.

► Construction :- It consists of two lobes being driven. One lobe is driver lobe. When one lobe rotates in clockwise direction the other rotates in anti-clockwise direction with very precise timing & clearances.



► Working :- Air is sucked into the inlet and it is forced around by the lobes and then pushed out of the discharge.

Figure

The amount of pressure a rotary lobe compressor can produce is very small compare to reciprocating compressor can do, therefore lobe compressor are referred as blowers, because they produce low pressure at a high volume.

- Air Treatment :-
1. Air receiver,
 2. Air moisture separator,
 3. Air Filter,
 4. Air Pressure Regulator,
 5. Air Lubrication
- } FRL unit

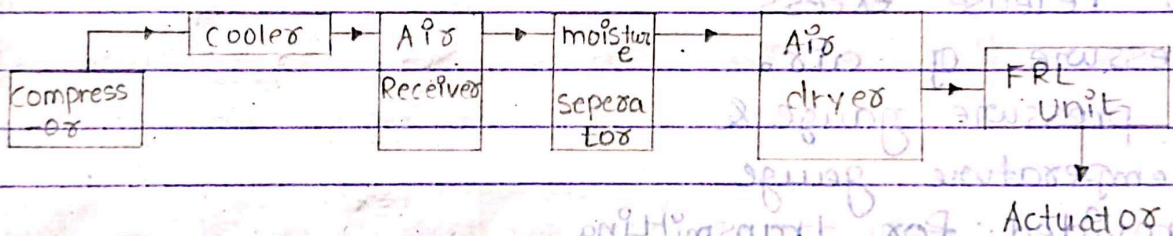


Figure Layout of Air treatment process

1. Air Receiver :- Air receiver is a part of air treatment process in pneumatic system. The main function of air receiver is to provide large capacity volume which increases the cycle time of compressor control system.

The receiver also Dampens pulsations from reciprocating compressor.

It also reduces the amount of moisture from the compressed air. The compressed air will be made more dryer in further moisture separator and air dryers.

Construction :- It is usually consist of cylindrical construction made of

steel. A safety valve is necessary

to release excess pressure of air.

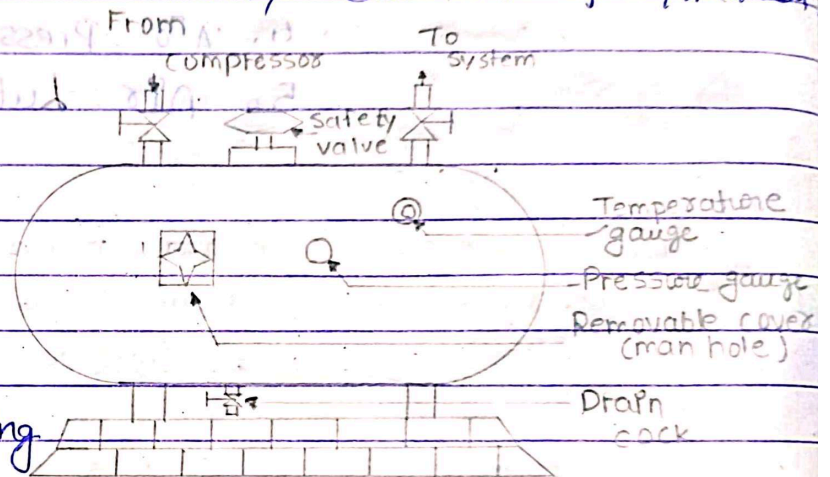
A pressure gauge & temperature gauge

provided for transmitting signal to electrical control.

A Drain cock allows removal of

condensed water and manhole

allows cleaning of in side chambers of air receiver.



Figure

:- Air Receiver

▷ Drying of compressed Air :-

Function :- Is to lower the dew point of the compressed air by removing the moisture from it. For simple applications, to remove excess humidity, we need simple after cooler, an air receiver, and a filter with condensate traps. However, to get high quality compressed air additional means of dehydration must be provided using dryer.

▷ Types of Air Dryer :-

1. Absorption type Dryer, 2. Adsorption type dryer,
3. Refrigeration dryer, 4. Membrane dryer.

▷ Absorption type Dryer :-

Absorption drying is a purely chemical process. The moisture in the compressed air forms a compound with drying agent like phosphoric pentoxide in the tank. This causes the drying agent to break down. It is then discharged in the form of a fluid at the base of the tank.

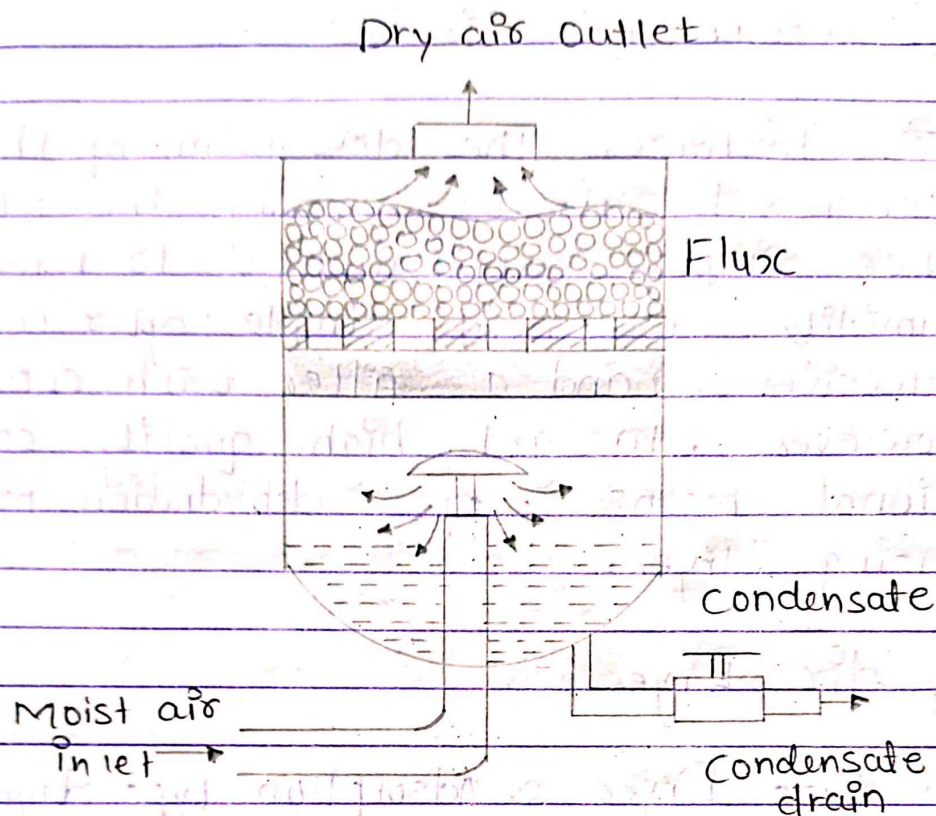
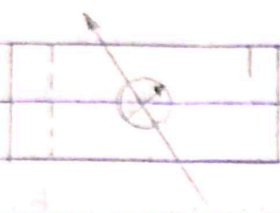


Figure - Absorption dryer

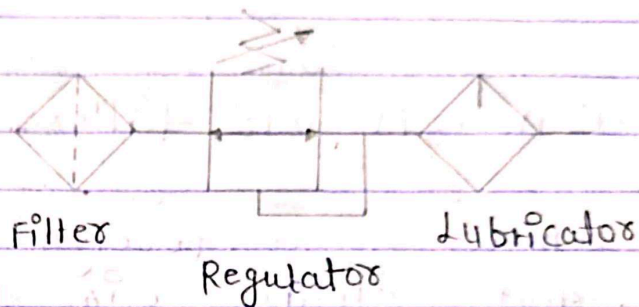
Oil vapour and oil particles are also separated in the absorption dryer. Large quantities of oil have an effect on the efficiency of the dryer. Therefore, it is advisable to include a fine filter in front of the dryer.

► FRL Unit

1. Filter - It is used for separate out or filter out contaminants present in the compressed air.



Simplified symbol



Figure

2. Regulator - It is pressure control device used for regulating pressure of compressed air to the desired pressure at a steady state condition.

3. Lubricator - It is a device which is used for addition of lubricating oil particles in compressed air for lubrication of sliding or moving pneumatic components.

Δ Air Filters :-

The purpose of the air filter is to clean the compressed air of all impurities and any condensate it contains.

a) Function of Air filters :-

- To remove all foreign matter and allow dry and clean air flow without restriction to regulator and then to the lubricator.
- To condensate and remove water from the air.
- To arrest fine particles and all solid contaminants from air.

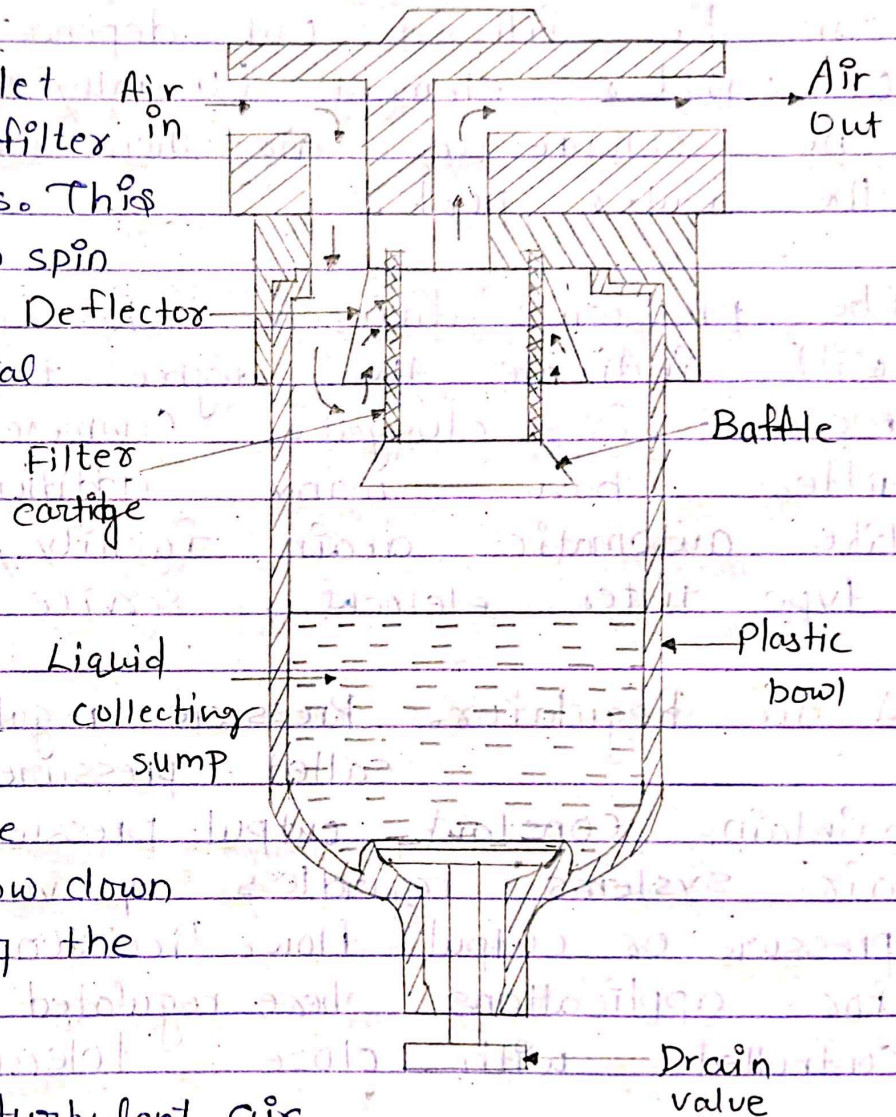
b) Construction :-

The construction of typical Cartridge type filter along with graphical symbols is shown in figure. It consists of filter cartridge, Deflector, bowl, water drain valve.

Filter bowl is usually made of plastic & transparent. For pressure more than 10 bar, bowl may be made of brass.

(c) Operation :-

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



A baffle prevents turbulent air from splashing water on

to the filter element. Figure :- Air Filter

The air, which has been pre-cleaned in this way, then passes through the filter element, where the fine dirt particles are filtered out.



The size of the dirt particles which can be filtered out depends on mesh size of filter element (usually 5-50 microns). The compressed air then exits through the outer port.

The pressure difference b/w inlet and outlet will indicate the degree to which the filter element is clogged. Commercially available filters have many additional features like automatic drain facility, coalescing type filter element, service life indicator etc.

Δ Air Regulator:- Pressure regulators, commonly called pressure-reducing valves, maintain constant output pressure in compressed air systems regardless of variations in input pressure or output flow. Precision regulators are for applications where regulated pressure must be controlled with close tolerances.

a.) **Function :-** The function of the air pressure regulator is to maintain working pressure virtually constant regardless of fluctuations of the line pressure and air consumption.

When the pressure is too low, it results in poor efficiencies and when the pressure is too high, energy is wasted and equipment performance decay faster.

In pneumatic system, pressure fluctuations occur due to variation in supply pressure or load pressure. It is therefore essential to regulate the pressure to match the requirement of load regardless of variation in supply pressure or load pressure.

b) Where to Regulate :-

Generally pressure is regulated in pneumatic system at two places :-

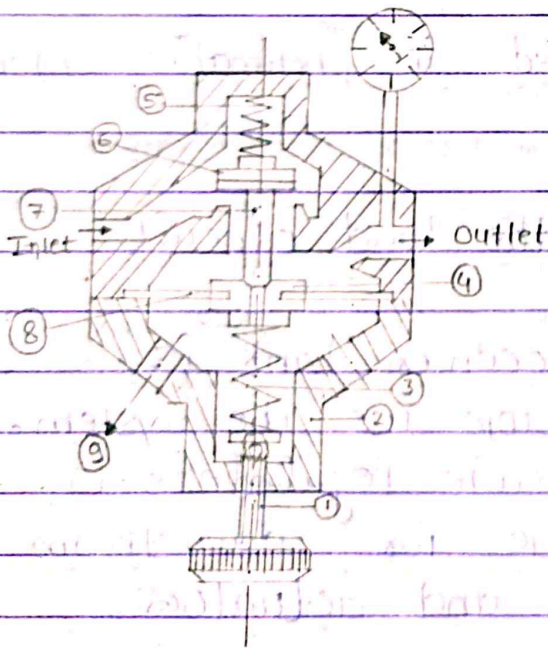
▪ At the receiver tank , ▪ In the load circuit

Pressure regulation at the receiver tank is required as a safety measure for the system.

In the load circuits, pressure regulators is used to regulate the pressure for downstream components such as valves and actuators.

▷ Relieving Or Venting Type Pressure Regulator :-

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



1. Adjusting screw
2. Housing
3. Spring
4. valve seat ring
5. Damper spring
6. valve Disc
7. valve plunger
8. Diaphragm
9. vent hole

Figure - Venting Type Pressure Regulator

- If the outlet pressure is low :-

Whenever the more compressed air is consumed on secondary side or load side, then load pressure reduces. Therefore less force acts on diaphragm. The opposing higher spring force pushes the diaphragm in such a way as to move the valve disc more and permitting more air to flow to secondary side and thus increasing the pressure again.

- If the Outlet pressure is high :-

Whenever the less compressed air is consumed on secondary side or load side, then load pressure increases. Therefore more force acts on diaphragm.

The opposing higher spring force pulls down the diaphragm in such a way as to move the valve disc less and permitting air to flow to vent hole and thus decreasing the pressure again.

A Lubricator :-

- A pneumatic lubricator injects an aerosolized stream of oil into an air line to provide lubrication to the internal working parts of pneumatic tools, and to other devices such as actuating cylinders, valves and motors. A lubricator should always be the last element in an FRL (Filter-Regulator-Lubricator) unit.

Δ Air Lubricator :-

► Function :- The function of air lubricator is to add a controlled amount of oil with air to ensure proper lubrication of internal moving parts of pneumatic components. Lubricants are used to

- To Reduce the wear of the moving parts
- Reduce the frictional losses
- Protect the equipment from corrosion

The lubricator adds the lubricating oil in the form of fine mist to reduce the friction and wear of moving parts of pneumatic components such as valves, packing used in actuators.

Excessive lubrication is undesirable. Excessive lubrication may result in

- Malfunctioning of components,
- Seizing and sticking of components after prolonged downtime.
- Environmental pollution.

► Operation :- The operation is similar to the principle of the carburettor. As air enters the lubricator its velocity is increased by a venturi ring. The pressure at the venturi ring will be lower than the atmospheric pressure and the pressure on the oil is atmospheric. Due to this pressure difference b/w the upper chamber and lower chamber, oil will be drawn up in a riser tube.

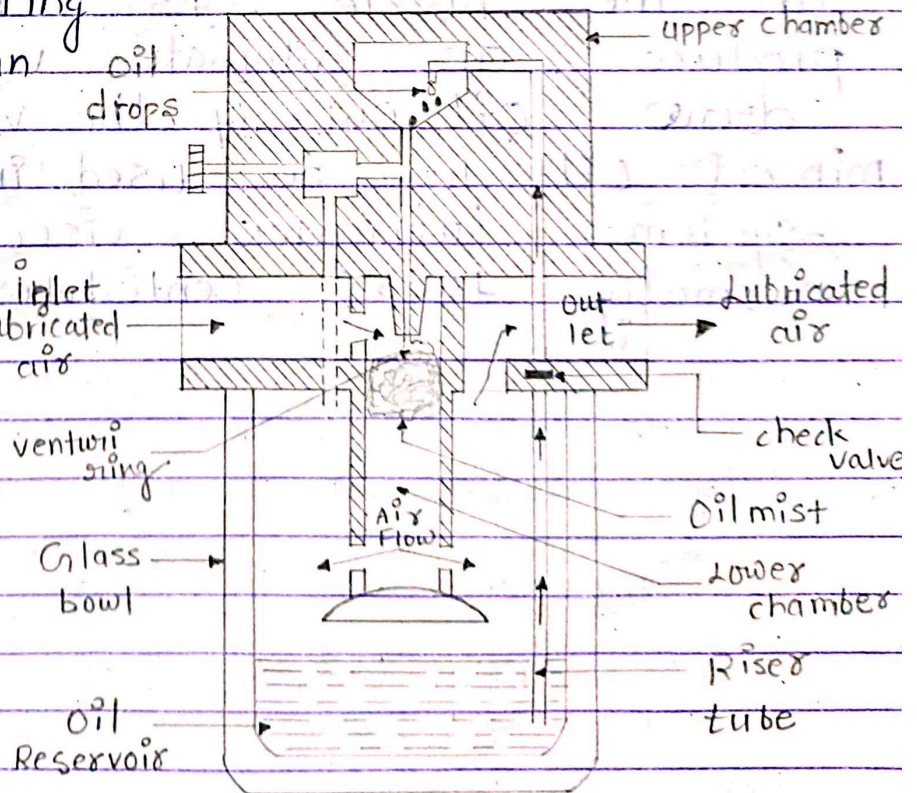


Figure:- Air Lubricator



Oil droplets mix with the incoming air and form a fine mist. The needle valve is used adjust the pressure differential b/w across the oil jet and hence the oil flow rate. The air-oil mixture is forced to swirl as it leaves the central cylinder so that large particles of oil is goes back to bowl and only the mist goes to outlet.

The lubricator starts to operate only when there is sufficient flow of air. If too little air is drawn off, the flow velocity at the nozzle is not sufficient to produce an adequate vacuum and hence to draw oil out of the vessel. Only thin mineral oil may be used in pneumatic system lubricator. viscosity ratings are normally 10-50 centistokes or SAE 10.

► Pneumatic Actuators :-

1. Axial Piston Motor :-

- In this motor, number of piston reciprocates in cylinder block.
- One side of these pistons are placed inside cylinder and another side of pistons are connected to swash plate.
- Pistons are connected to swash plate at equal distance from center of swash plate.

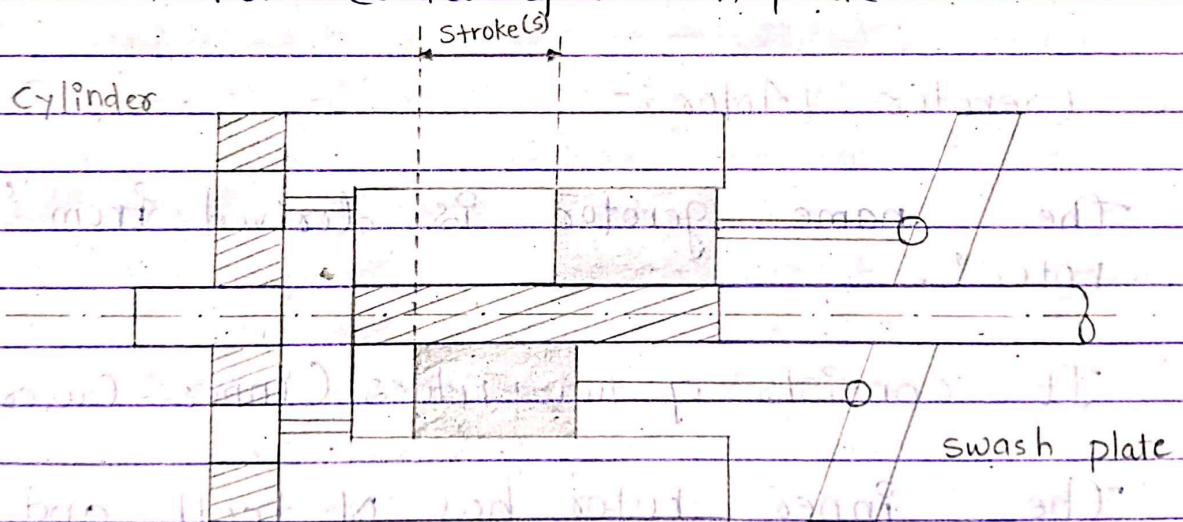
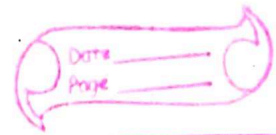


Figure - Axial Piston Motor

- Motors generate torque by pressure of fluid acting on one end of piston.



Due to pressure, piston reciprocates inside the cylinder block.

- ▶ Pressure acting on one end of piston generates a force against an angled swash plate.
- ▶ Due to angle, this force has two components, one is tangential force on swash plate and another is axial force on swash plate.
- ▶ Due to tangential force on swash plate, rotation is started.

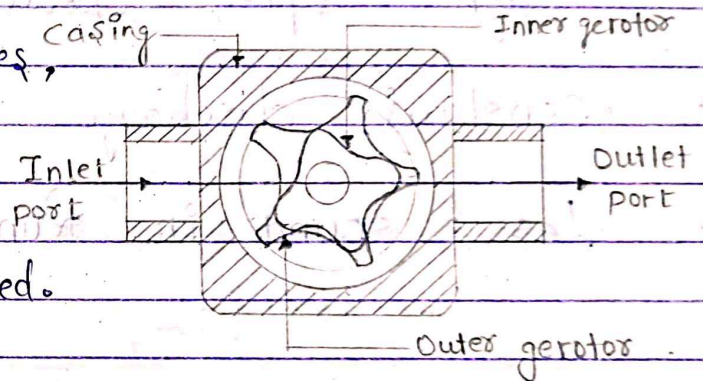
2. Gerotor Motor :-

- ▶ The name gerotor is derived from 'Generated rotor'.
- ▶ It consists of two rotors (inner & outer rotor).
- ▶ The inner rotor has N teeth and the outer rotor has $N+1$ teeth.
- ▶ The inner rotor is located off center and both rotors rotate.



- ▶ During the rotation, volume of each partition changes continuously.
- ▶ Therefore any given volume first increases and then decreases.
- ▶ This vacuum creates suction and thus this part of cycle sucks the fluid.

- ▶ As the volume decreases, compression occurs.
- ▶ During this compression period, fluid can be pumped.



- ▶ The close tolerance b/w the rotors acts as a seal b/w the suction and discharge ports.

Figure-Gerotor Motor

- ▶ The rotor and idler (outer rotor) teeth mesh completely to form a seal equidistant from discharge and suction ports.

► This seal forces the liquid out of the discharge port.

► The flow output is uniform and constant at outlet.

→ Advantages :-

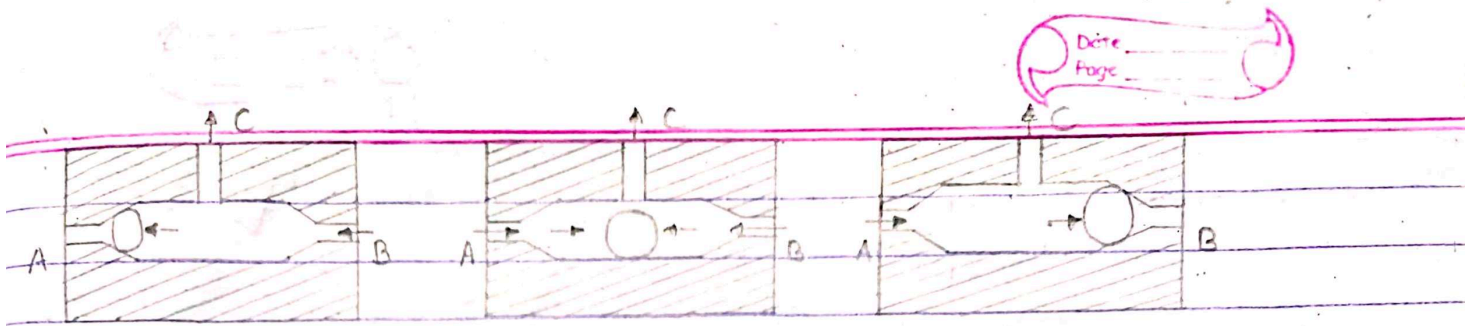
- High Speed operation.
- Constant discharge in all pressure condition.
- Less sound in Running condition.

▷ Difference Between Electrical, Hydraulic & Pneumatic system :-

No.	Electrical	Hydraulic	Pneumatic
1.	Danger of electric shock.	Electric shock proof.	Electric shock proof.
2.	Danger of sparks due to which fire hazards.	Danger of fire hazard due to leakage of oil.	No chance of fire hazard, Better in mines.
3.	It takes more time to pick up the speed.	It is very slow for its operation.	It is very quick and fast operation.
4.	Design & construction is complicated and costly.	Simple in design, but rigid in construction, medium cost.	very simple in construction and design, cheaper in cost.
5.	If run for longer time, its temp. goes on increasing, which may be dangerous to the windings.	The temp. increases negligibly due to friction. But does not create any serious problem.	Harder it run, cooler it works. This is bcoz, the expanding air in the motor creates cooling effect.

6.	It can't be used in hot surroundings. Windings may burn out.	It should not be run in hot surroundings. Oil viscosity reduces with increase in temp.	Due to the above property, it can be used in hot surroundings up to 125°C .
7.	Dust and moisture damage it seriously due to corrosion.	No corrosion. But oil and dust make the place dirty and slippery.	Absolutely dust resistant and corrosion resistant.
8.	Less Noise	Less Noise	Noisy unless its exhaust port is muffled.

► Shuttle valve :- It is also known as double control valve or double check valve. A shuttle valve has two inlets and one outlet. At any one time, flow is shut off in the direction of whichever inlet is unloaded and is open from the loaded inlet to the outlet. A shuttle valve may be installed, for example, when a power unit (cylinder) or control unit (valve) is to be actuated from two points, which may be remote from one other.



It has two inlet ports, A and B and one outlet port C. It has OR type of logic function.

When fluid under pressure is supplied through any of the two inlet ports, inlet port A or inlet port B, there will be supply from the outlet port C.

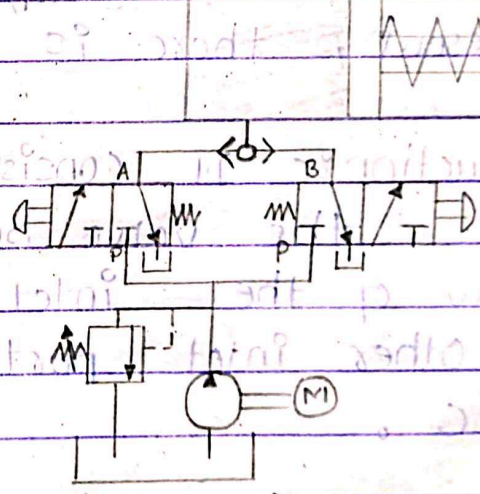
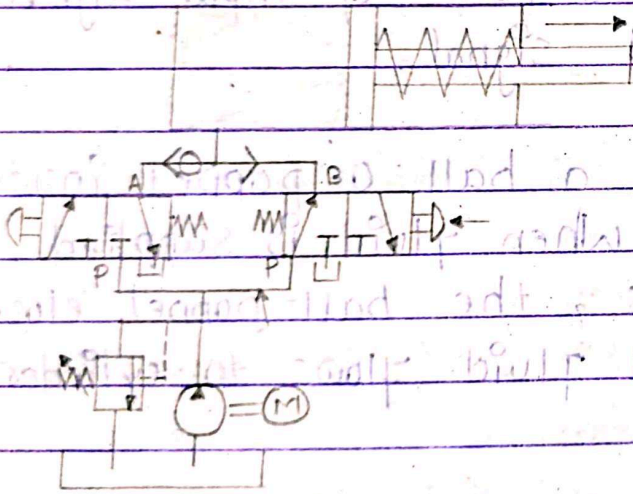
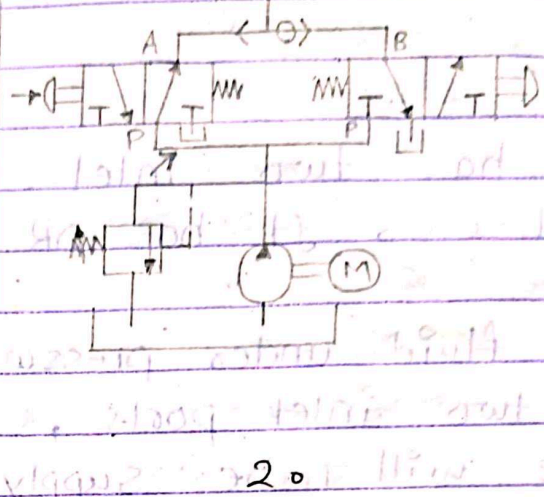
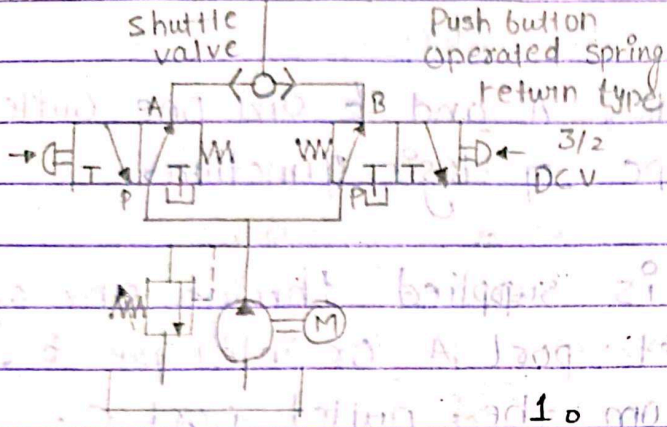
In other words, when any one or both of input signals is present, there is output signal.

▷ Construction:- It consists of a ball or poppet inside the valve body. When fluid is supplied to any of the inlet ports, the ball-poppet closes the other inlet port and fluid flows to cylinder port - C.

Truth Table	Sl. No.	Input - A	Input - B	Output
	1.	yes	yes	yes
	2.	yes	no	yes
	3.	no	yes	yes
	4.	no	no	no



Single acting cylinder



▷ Quick Exhaust valve :- A quick exhaust valve is a typical shuttle valve. The quick exhaust valve is used to exhaust the cylinder air quickly to atmosphere. In many

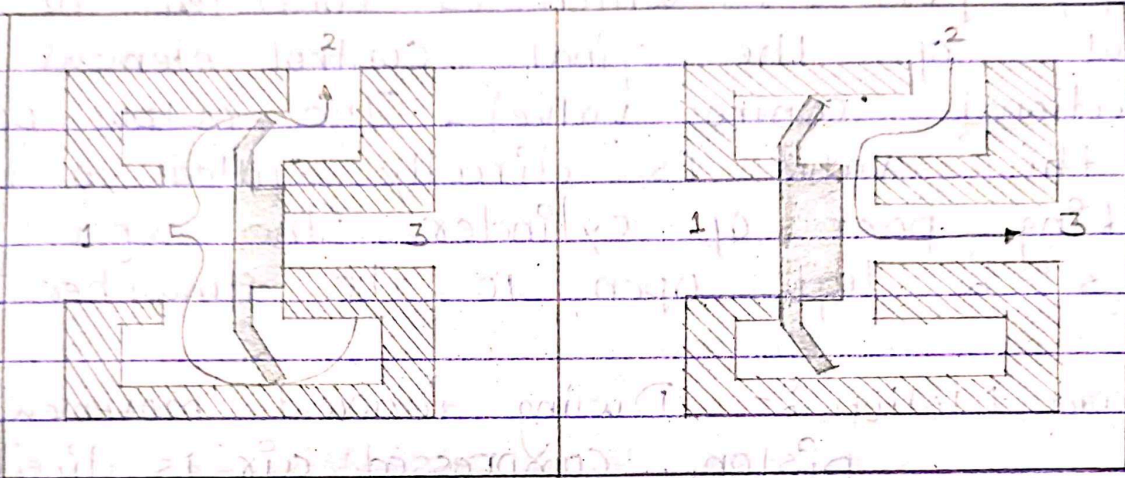


Figure-Functional diagram of Quick Exhaust valve

applications especially with single acting cylinders, it is a common practise to increase the piston speed during retraction of the cylinder to save the cycle time. The higher speed of the piston is possible by reducing the resistance to flow of the exhausting air during the motion of cylinder. The resistance can be reduced by expelling the exhausting air to the atmosphere quickly by using Quick exhaust valve.

▷ Construction & Operation :-

It consists of a movable disc (also called flexible ring) and three ports namely supply port - 1, which is connected to the output of the final control element (Directional control valve). The output port - 2, of this valve is directly fitted to the working port of cylinder. The exhaust port - 3, is left open to the atmosphere.

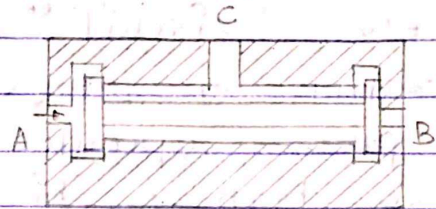
▲ **Forward Motion :-** During forward movement of piston, compressed air is directly admitted behind the piston through 1 and 2 port - 3 is closed due to the supply pressure acting on the diaphragm. Port - 3 is usually provided with a silencer to minimise the noise due to exhaust.

▲ **Return Motion :-** During return movement of piston, exhaust air from cylinder is directly exhausted to atmosphere through opening 3 (usually larger and fitted with silencer). Port - 2 is sealed by the diaphragm. Thus exhaust air is not required to pass through long and narrow passages in the working line and final control valve.

► Twin Pressure valve :-

△ A twin pressure valve Input is shown in figure.

- A is Present

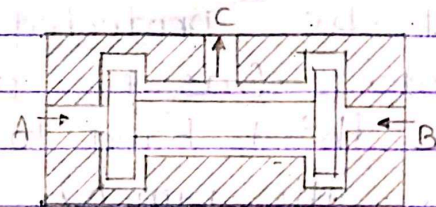


no output at -C

(a)

△ It has two inlet ports, A and B and one outlet port C.

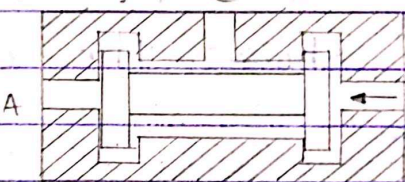
△ This valve has AND logic function.



Both inputs - A & B are present.
hence output at - C is present.

(b)

△ AND logic function statement is "When both of input signals are present, then only there will be output signal."



Input - B is presented
no output at - C

(c)

△ This valve consists of a spool inside the valve body. When working fluid is supplied from only one inlet port, the spool closes the outlet. If working fluid is supplied from both of inlet ports, then only the outlet port opens.

AND logic is used in safety circuit "two hand operation of press" where, the press operator has to engage both of his hands to start or operate the press, thereby, his hands will be protected from accident (as he don't have any third hand to be left below the punch).

Truth Table for twin pressure valve

Input A	Input B	Output C
yes	yes	yes
yes	no	no
no	yes	no
no	no	no

► Application of Twin Pressure Valve (AND logic valve)

△ Figo shows the application of twin pressure valve.

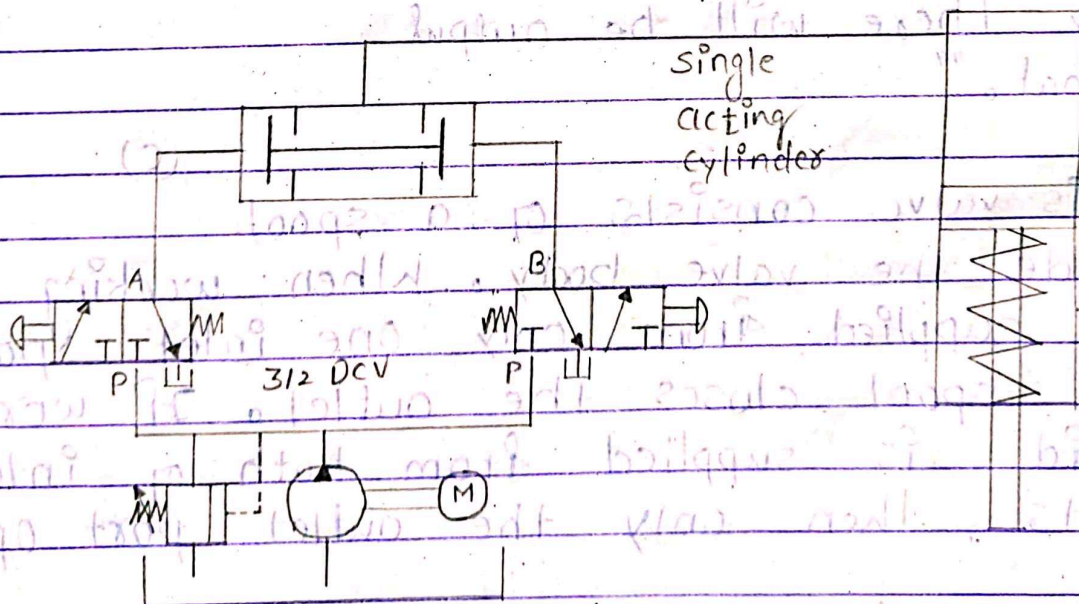


Figure:- Circuit Diagram of Twin pressure valve

- △ The circuit has two "push button operated spring return type normally closed $3/2$ direction control valves", a single acting cylinder and a twin pressure valve.
- △ In normal position, the single acting cylinder is in retracted position.
- △ If and only if, the push buttons of both valves are pressed together, then only the cylinder will extend.
- △ Such circuits are safety circuits called "two hand operations circuits" which safeguard the hands of the operator in case of hydraulic press or pneumatic press.
- △ Both hands of the operator are made to engage in pressing the buttons, and thereby the chance of his hand coming in blow the punch and die is avoided.
- △ This circuit is AND logic circuit.

► Time delay valve :-

TDV is used to have delay b/w two operations.

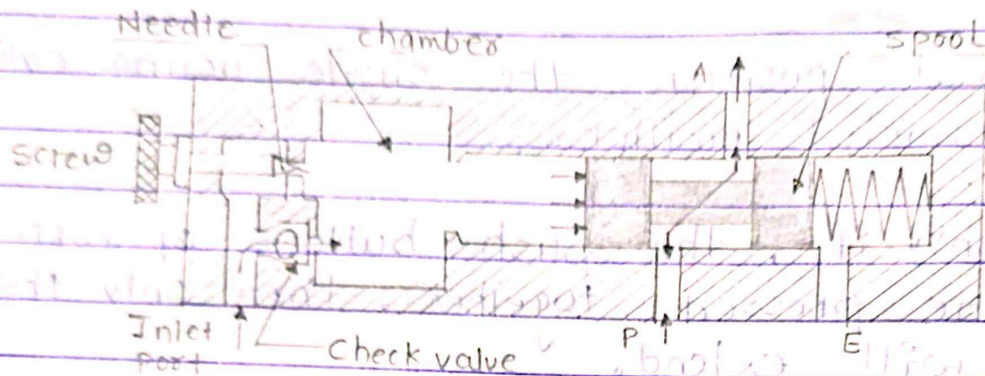


Figure :- Actuated Position

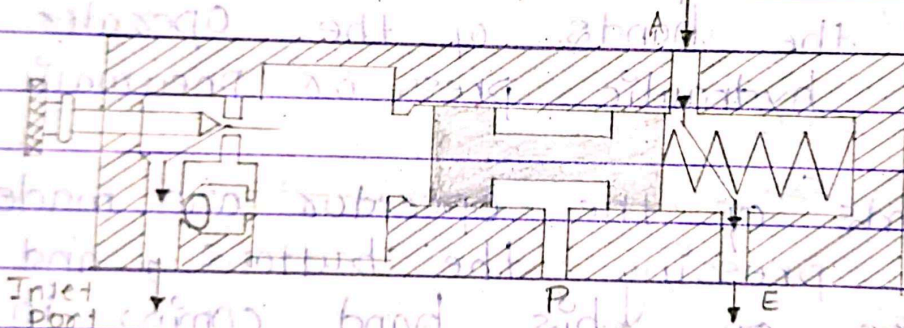


Figure :- Normal position

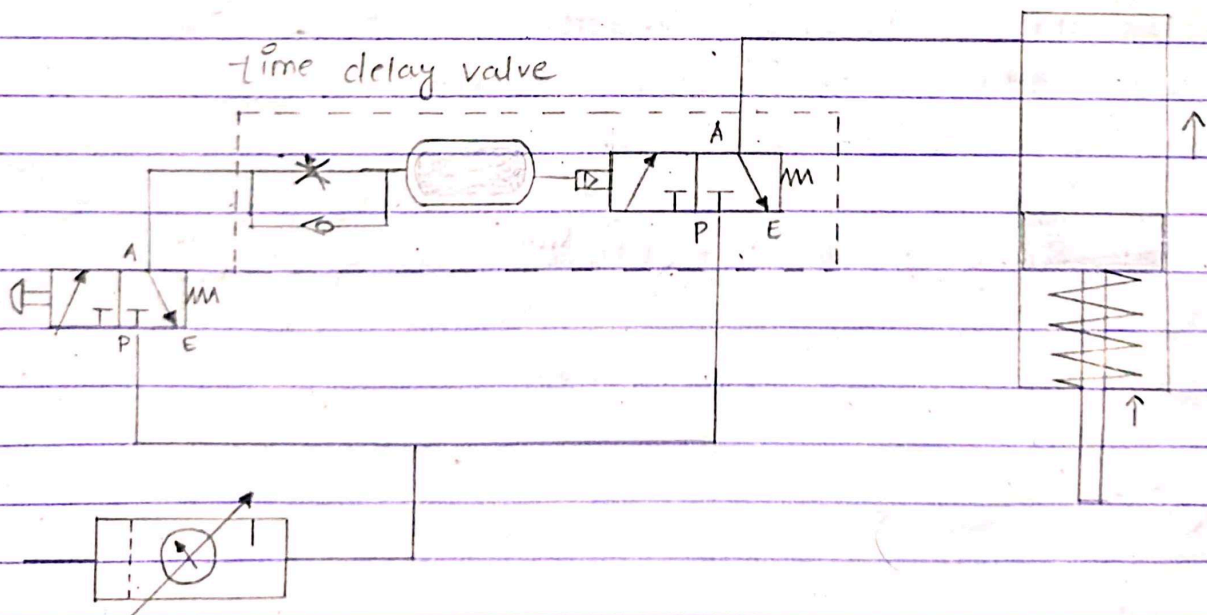
Consider port - A is connected to a single acting cylinder.

When compressed air is supplied to inlet port, it flows through the check valve

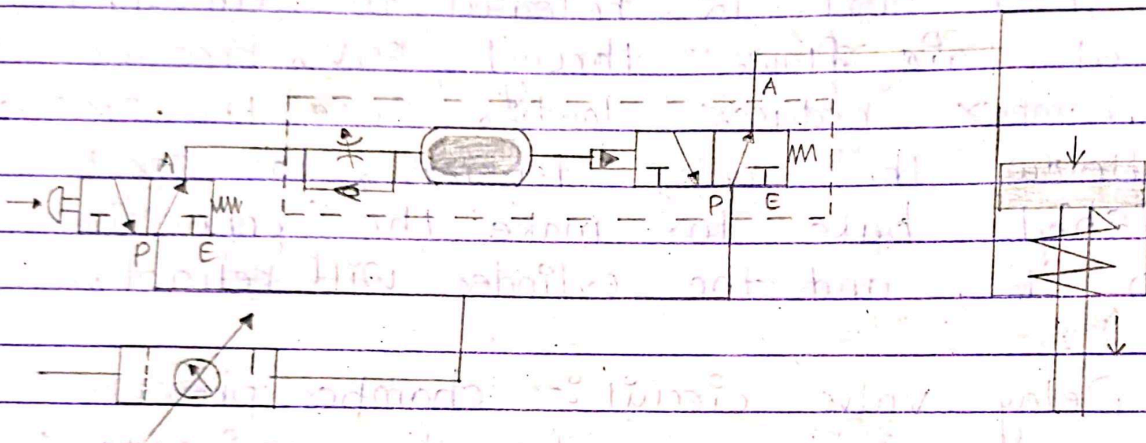
and fills in the chamber. pressure is exerted on spool and P to A connection is made, and the cylinder extends.

When inlet port is released to atmosphere, compressed air flows through FGV. Pressure in chamber reduces slowly. Once the pressure falls below the spring tension, the spool will shift back to make the connection A to E, and the cylinder will retract.

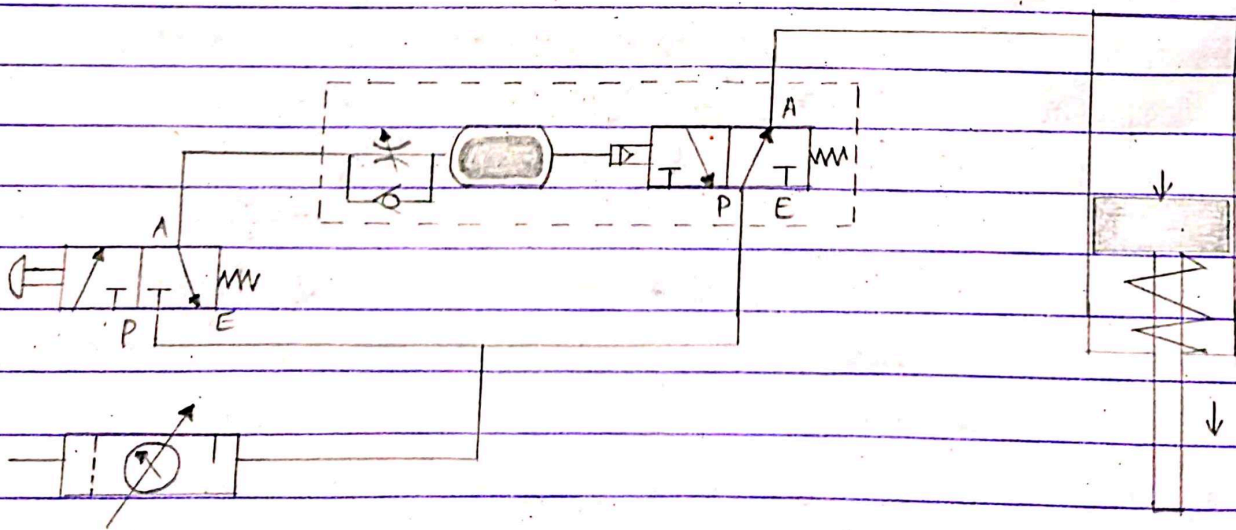
1. Time Delay valve circuit :- chamber pressure is less than spring tension, cylinder retracts.



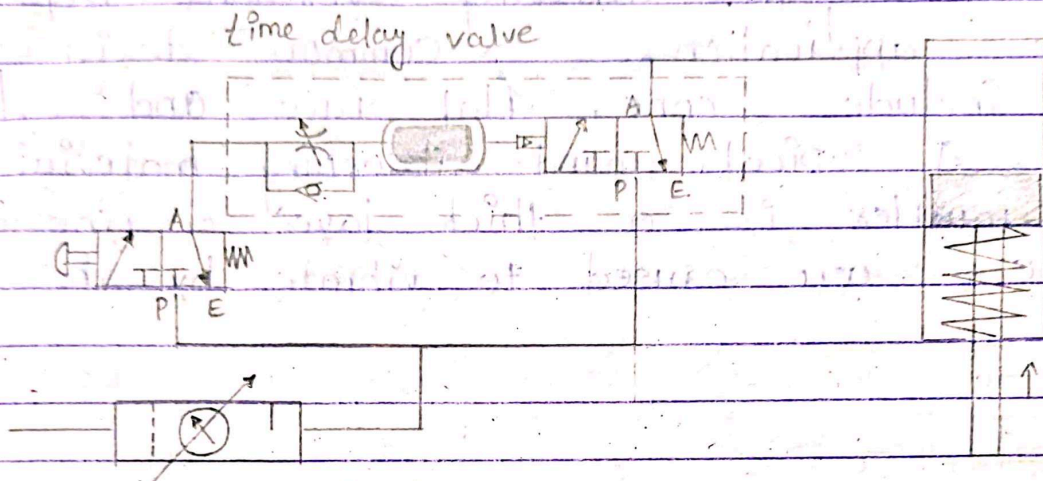
2. $3/2$ Dcv is pressed, chamber pressure increases, cylinder extends.



3. $3/2$ Dcv is released, chamber pressure is falling slowly, cylinder remains extended.



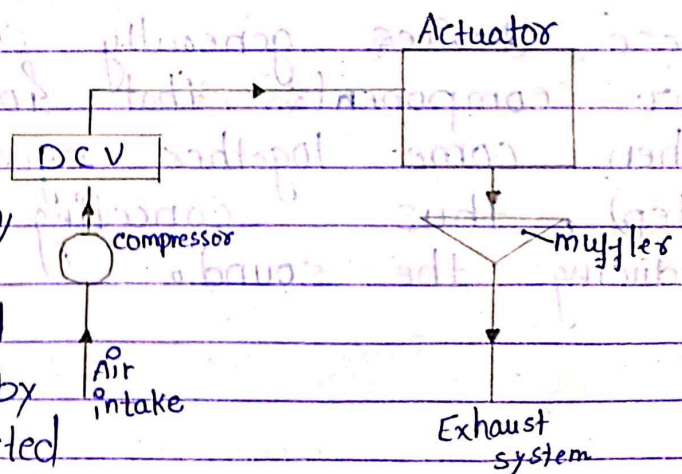
4th chamber pressure is less than spring tension, cylinder retracts.



► Accessories :- Muffler :- A muffler is a device for decreasing the amount of noise emitted by the exhaust from pneumatic system.

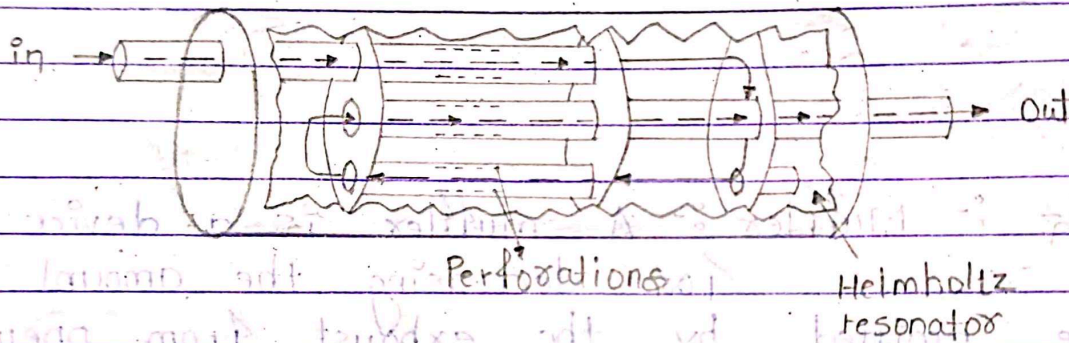
Noise results when fast-moving, turbulent air exiting a port collides with the surrounding static air.

To be efficient as a sound reducer, a muffler must decrease the velocity of the exhaust gases and either absorb sound waves or cancel them by interference with reflected waves coming from the same source.



► Construction :-

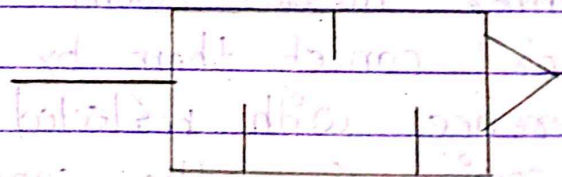
Mufflers can be constructed of plastic or metals like brass and stainless steel. They come in differing versions depending on the application. Common design styles include cone, flat-face and cylindrical shapes. A typical sound-absorbing material used in a muffler is a thick layer of fine fibers, the fibers are caused to vibrate by the sound



waves, thus converting the sound energy to heat. Mufflers that attenuate sound waves by interference are known as reactive mufflers.

These devices generally separate the waves into two components that follow different paths and then come together again (out of phase/out of step), thus canceling each other out and reducing the sound.

Symbol



In the typical reactive design shown in the illustration, the arrows indicate the flow of exhaust gas through a set of tubes and chambers inside the muffler. One important chamber is known as the Helmholtz resonator. This chamber is of a dimension carefully tuned to reflect and cancel sound waves of specified frequencies.

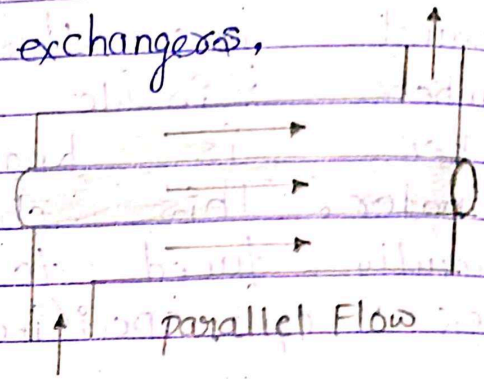
In addition, the tubes can be perforated with small holes that allow the reflection and interference of sound waves of other frequencies. The result is the attenuation of sound across a range of desired frequencies.

► Heat Exchangers :-

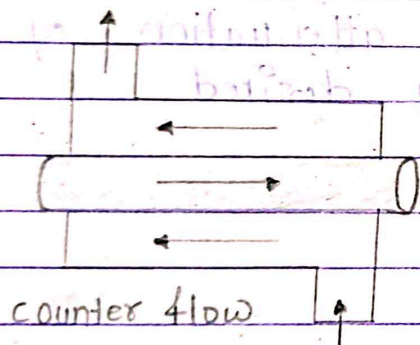
- A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another.
- They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing and sewage treatment.

There are mainly 3 types of flow arrangements.

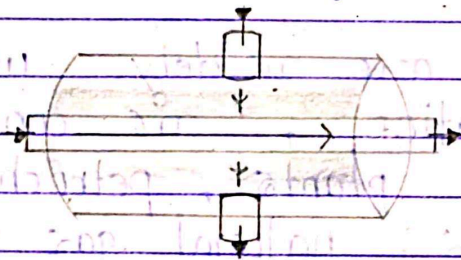
1. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side.



2. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient.



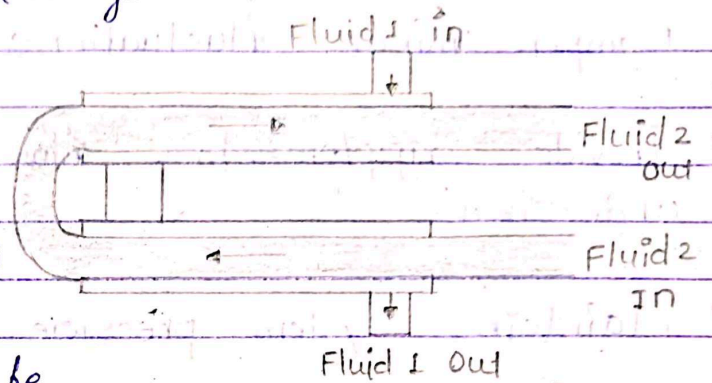
3. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.



▷ Double Pipe Heat Exchanger :-

◦ It is also known as concentric tube heat exchanger.

◦ In this heat exchanger the fluid to be cooled or heated passes through the tube 2 (dark) and the other fluid is passed through tube 1 (light) to absorb or release the heat.



Figure

◦ Advantages :- cheap for both design and maintenance.

◦ Disadvantages :- Low efficiency and requires large space.

▷ Accumulator :-

An Accumulator is a device that allows hydraulic or pneumatic system to store oil, air under pressure for an extended period of time.

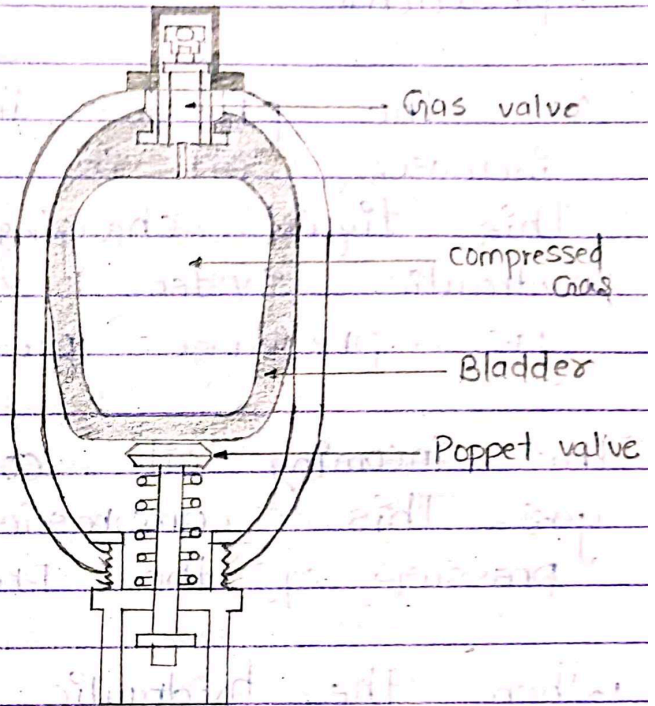
► Uses of Accumulators :-

- Energy Recovery.
- Absorb system shocks.
- Dampen minor fluctuations in system pressure or flow.
- Provide supplementary flow (e.g. if the pump is undersized)
- Maintain system pressure.
- Store energy (emergency power) in the form of fluid under pressure.
- Noise elimination.
- Absorption of thermal expansion.
- Leak compensation.
- compensation for slow pump controller response.

► Types of Accumulators :-

1. Bladder Type ;
2. Piston Type

▷ Bladder Type Accumulator - A bladder type accumulator, sometimes known as a hydro-pneumatic accumulator, is a metal tank that contains a rubber bladder filled with compressed gas. There is also a poppet valve in the discharge port and a gas valve used to precharge the bladder.



Precharge:- The pressurized gas in the accumulator.

Charge:- The hydraulic fluid in the accumulator. Figure

As the bladder is being precharged, it will expand to the point of forcing the poppet closed. The poppet is there to ensure that the bladder can't expand out into the discharge port.

Typically, the accumulator precharge is set to b/w 60% and 80% of the minimum system pressure.

That way the bladder doesn't expand enough to close the poppet during normal operation.

As the pressure in the hydraulic system increases, oil is forced into the accumulator. This liquid charging is possible when the hydraulic system pressure is greater than the gas precharge pressure.

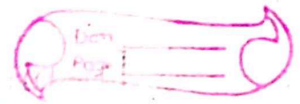
The incoming oil compresses the bladder and the gas. This compression in turn increases the pressure of the precharge gas.

When the hydraulic system pressure decreases, the bladder expands again, forcing the oil back out.

It is this constant seeking of equilibrium b/w the pressure of the hydraulic oil and the pressure of the precharge gas that drives the function of the bladder style accumulator.

▷ Advantages :-

□ very expensive to system standards.



- Precharge gas seldom needs maintaining up.
- Generally less expensive than piston accumulators.
- Lighter in weight than the equivalent sized piston model.
- ▷ Disadvantages :-
 - Bladder may become brittle & burst.
 - Compressing the bladder too much can damage it.
 - Cannot be fully discharged (cycled right to the bottom) too frequently without causing damage.

UNIT- 5.0

Pneumatic Circuits

► Air - hydraulic Application :-

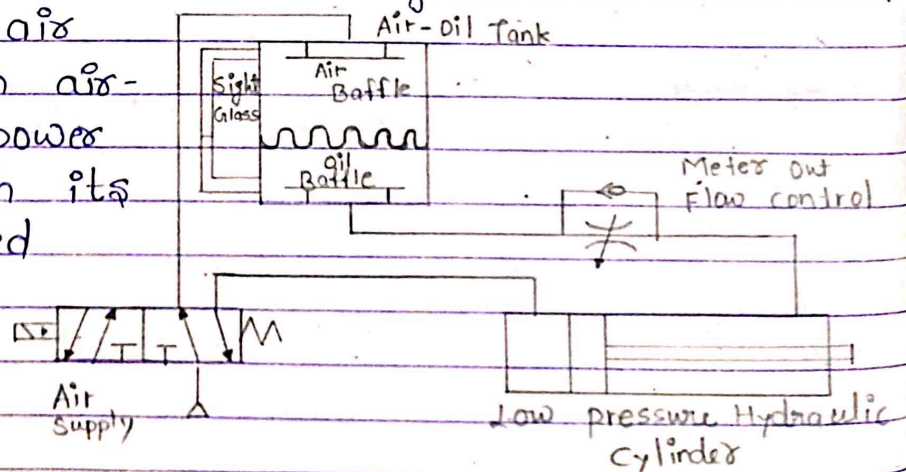
Compressed air is suitable for low power systems, but air compressibility makes it difficult to control actuators smoothly and accurately. Some low power systems need smooth control, rigidity, or synchronization capabilities normally associated with oil hydraulics. All of these features are available to low power circuits by using compressed air as power and oil for control. Purchased or special built air-over-oil circuits provide smooth control when power requirement is low.

► Air - oil Reservoir or tank :- Figure shows a single tank air-over-oil

system with an air valve piped to an air-over-oil tank to power the rod end with its other port connected directly to the cylinder cap end.

A flow control valve in the oil

line controls the cylinder advance speed.



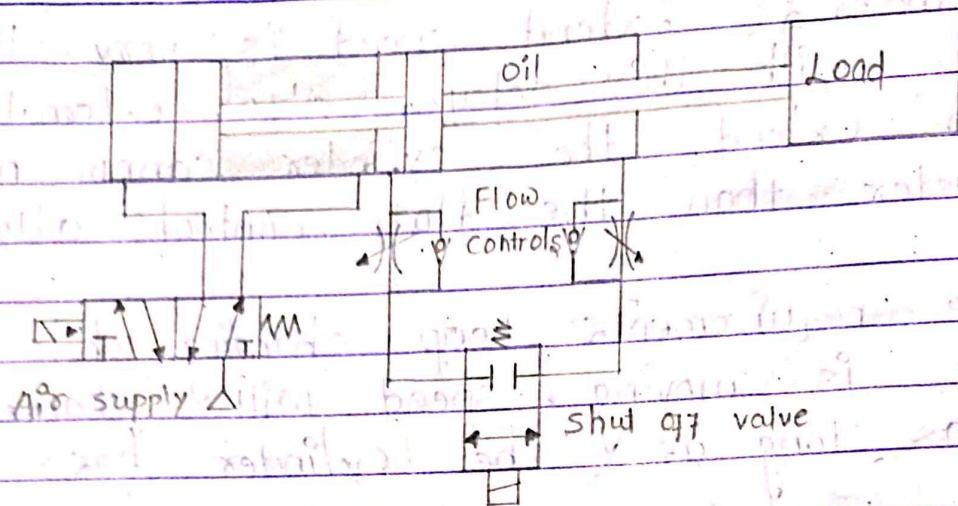
The cylinder's extend speed is very slow and controllable with this setup. Also, external forces trying to extend the cylinder cannot make it move faster than the flow control allows.

If force requirements keep changing while the cylinder is moving, speed will change very little as long as the cylinder has enough force.

Notice the baffles in the air-oil tank. The top baffle keeps incoming air from shooting into the oil, causing aeration. The bottom baffle stops any vortexing that might allow air to enter the cylinder as the tank level lowers.

► Air-oil cylinder :-

Figure shows a tandem cylinder piped for speed control and mid-stroke stopping. A tandem cylinder unit provides the same results as an air-over-oil tank system.



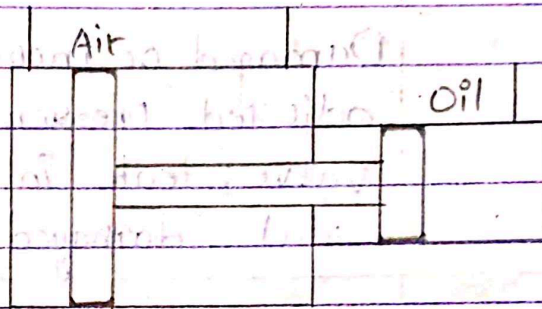
:- Figure

An air valve piped to the single-rod cylinder gives directional control. Install meter out flow controls and a shut-off valve in the line b/w ports on the double-rod cylinder.

The double rod end cylinder is completely full of oil and sealed against leakage. A small makeup tank attached to the transfer line, with a check valve b/w it and the cylinder port, allows oil to enter the cylinder when needed.

▷ Air - Oil Intensifier :- When a circuit calls for a small volume of high-pressure oil or air, consider using an intensifier - Sometimes called a Booster.

Most cylindrical manufacturers build air-or-hydraulic-powered intensifiers. Or you can use off-the-shelf cylinder parts to



assemble your own booster. Also, intensification is a natural function of single-rod cylinder and motor-type flow dividers.

Figure pictures the symbol for an air-oil-intensifier. While the symbol shows two pistons with different diameters, the actual intensifier consists of a piston pushing a rod. The large-area air piston pushes a small-area hydraulic ram against trapped oil. The capability is indicated by the area ratio. If the air piston has a 5-in. diameter and the oil piston has a 1-in. diameter, the area ratio is 25:1. With this area ratio, 80 psi acting on the air piston produces 2000 psi at the hydraulic piston.

► Common troubles in Pneumatic system causes and Remedies :-

Problem	Causes	Remedy
Pressure too low	Damaged or incorrectly adjusted pressure regulator valve, leak in system, seal damaged.	Replace or readjust regulator. Repair or renew damaged parts.
Improper functioning of filter	Over-contamination in filter unit.	clean or replace filter element regularly.
DCV not changing its position.	Valve spool stuck due to impurities b/w spool & sleeve.	Clean or replace valve.
No movement of cylinder	Pressure too low, piston leaks	check pressure at cylinder & adjust the pressure to circuit requirements. Replace piston seals.
Erratic movement of cylinder	Load misalignment, Large difference b/w static & dynamic friction.	Re-align cylinder & load, Install flow control valve to create back pressure.

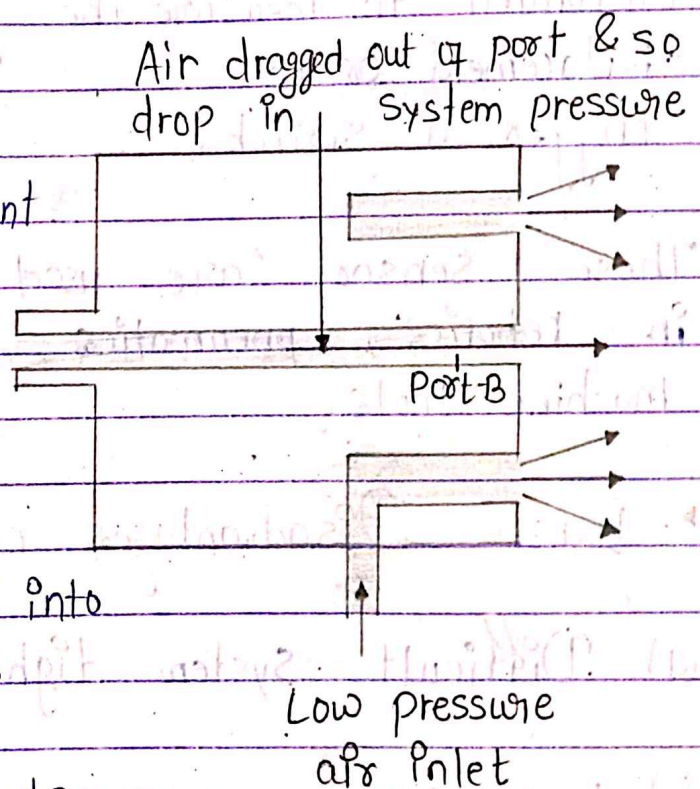
Contamination in circuit.	Improperly filtered feed pipes, Burrs inside piping components	Add prefilters, Disconnect cylinder from pipes & remove burrs
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► **Sensors :-** It is a transducer which is used to sense any change in physical quantity.

► **Pneumatic sensors :-**

These are used to measure the displacement as well as to sense the proximity of an object close to it.

The displacement and proximity are transformed into change in air pressure.



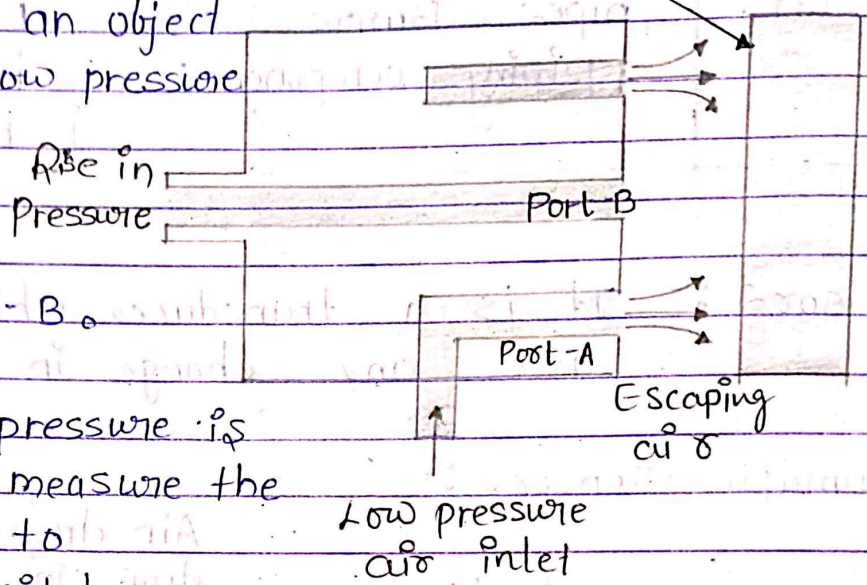
It comprises of three ports. Low pressure air is allowed to escape through port A.

:- Figure

In absence of any obstacle/object, this low pressure air escapes and in doing so, reduces the pressure in the port-B.

Object blocking escaping air increases pressure in system

However when an object obstructs the low pressure air (Port A), there is rise in pressure in output port - B.



This rise in pressure is calibrated to measure the displacement or to trigger a switch.

Figure

These sensors are used in robotics, pneumatics and for tooling in CNC machine tools.

► Basic Disadvantages of Pneumatic systems :-

- (a) Difficult system tightness.
- (b) Low working pressure compared with the hydraulic systems due to the tightness problems and compressor design (within 10 bar for industrial systems and more than 200 bar for aerospace systems).

(c) Difficulty of holding pneumatic actuators at intermediate positions.

(d) Delay of actuators' response due to the time needed for filling the long lines with compressed air.

(e) The variation of pressure in air reservoirs with temperature.

(f) The possibility of the condensation of humidity and the freezing of condensed water at low temperatures.

(g) Special lubricators are needed due to the poor lubricity of air.

(h) Danger of explosion.