MODULE 1: INTRODUCTION TO FLUID POWER SYSTEMS

Fluid power system: components, advantages and applications. Transmission of power at static and dynamic states. Pascal's law and its applications.

Fluids for hydraulic system: types, properties, and selection. Additives, effect of temperature and pressure on hydraulic fluid. Seals, sealing materials, compatibility of seal with fluids. Types of pipes, hoses, and quick acting couplings. Pressure drop in hoses/pipes. Fluid conditioning through filters, strainers, sources of contamination and contamination control, heat exchangers.

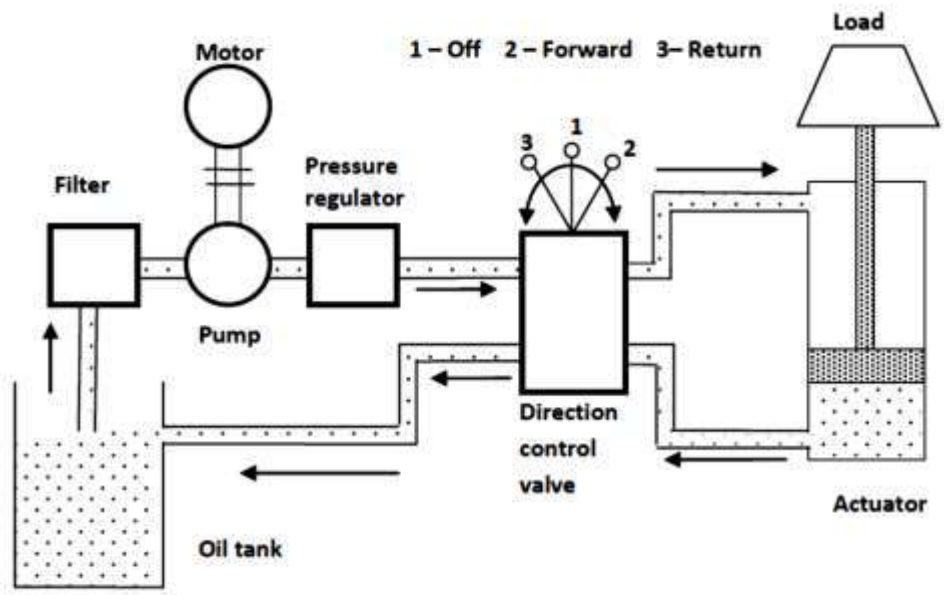
FLUID POWER SYSTEM

Fluid Power is the technology that deals with the generation, control, and transmission of power, using pressurized fluids. Fluid power is called ***hydraulics*** when the fluid is a liquid and is called ***pneumatics*** when the fluid is a gas.

Hydraulic systems use liquids such as petroleum oils, synthetic oils, and water. Pneumatic systems use air as the gas medium because air is very abundant and can be readily exhausted into the atmosphere after completing its assigned task.

COMPONENTS OF A FLUID POWER SYSTEM:

Hydraulic System:



There are six basic components required in a hydraulic system:

1) A tank (reservoir) to hold the hydraulic oil.

2) A pump to force the oil through the system.

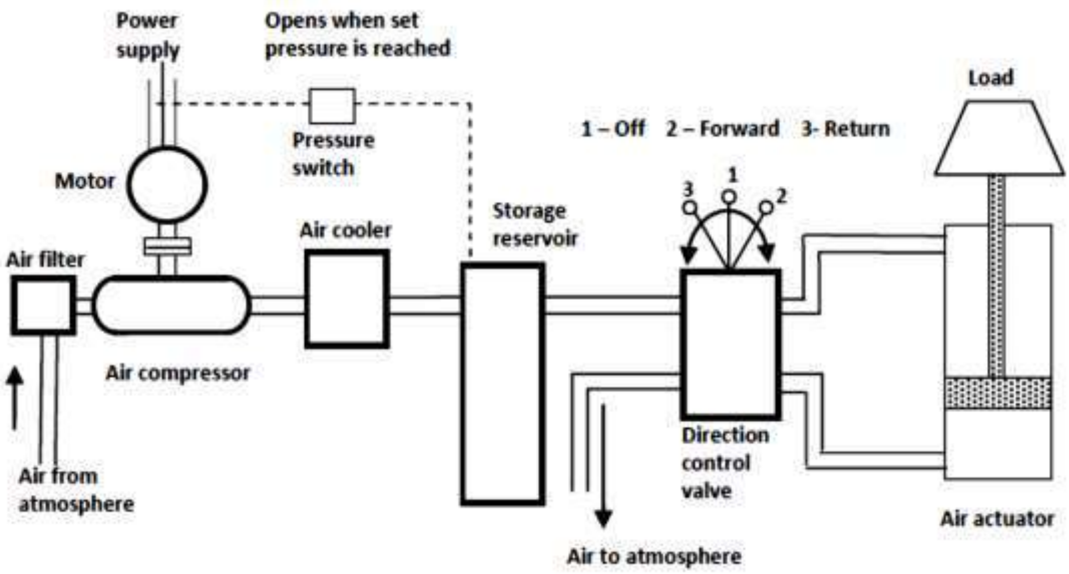
3) An electric motor or other power source to drive the pump.

4) Valves to control oil direction, pressure, and flowrate.

5) An actuator to convert the pressure of the oil into mechanical force to do the useful work.

6) Piping to carry the oil from one location to the other.

Pneumatic System:



Pneumatic systems have components that are similar to those used in hydraulic systems.

1) An air tank to store a given volume of compressed air.

2) A compressor to compress the air that comes directly from the atmosphere.

3) An electric motor or other prime mover to drive the compressor.

4) Valves to control air direction, pressure and flowrate.

5) Actuators, which are similar in operation to hydraulic actuators.

6) Piping to carry the pressurized air from one location to another.

ADVANTAGES OF FLUID POWER SYSTEM:

The advantages of a fluid power system are as follows:

1) Fluid power systems are simple, easy to operate and can be controlled accurately: Fluid power gives flexibility to equipment without requiring a complex mechanism. Using fluid power, we can start, stop, accelerate, decelerate, reverse or position large forces/components with great accuracy using simple levers and push buttons.

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) Multifunction control: A single hydraulic pump or air compressor can provide power and control for numerous machines using valve manifolds and distribution systems.

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

5) Constant force or torque: Fluid power systems can deliver constant torque or force regardless of speed changes.

6) 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.

7) Low weight to power ratio: The hydraulic system has a low weight to power ratio compared to electromechanical systems. Fluid power systems are compact.

8) Fluid power systems can be used where safety is of vital importance: Safety is of vital importance in air and space travel, in the production and operation of motor vehicles, in mining and manufacture of delicate products.

APPLICATIONS OF FLUID POWER:

1) Agriculture: Tractors and farm equipments like ploughs, movers, chemical sprayers, fertilizer spreaders.

2) Aviation: Fluid power equipments like landing wheels on aeroplane and helicopter, aircraft trolleys, aircraft engine test beds.

3) Building Industry: For metering and mixing of concrete ingredients from hopper.

4) Construction Equipment: Earthmoving equipments like excavators, bucket loaders, dozers, crawlers, and road graders.

5) Defence: Missile-launch systems and Navigation controls

6) Entertainment: Amusement park entertainment rides like roller coasters

7) Fabrication Industry: Hand tools like pneumatic drills, grinders, bores, riveting machines, nut runners

8) Food and Beverage: All types of food processing equipment, wrapping, bottling

9) Foundry: Full and semi-automatic moulding machines, tilting of furnaces, die casting machines

10) Material Handling: Jacks, Hosts, Cranes, Forklift, Conveyor system

TRANSMISSION OF POWER AT STATIC AND DYNAMIC STATES:

A hydrostatic system uses fluid pressure to transmit power. Hydrostatics deals with the mechanics of still fluids and uses the theory of equilibrium conditions in fluid. The system creates high pressure, and through a transmission line and a control element, this pressure drives an actuator (linear or rotational). The pump used in hydrostatic systems is a positive displacement pump. An example of pure hydrostatics is the transfer of force in hydraulics.

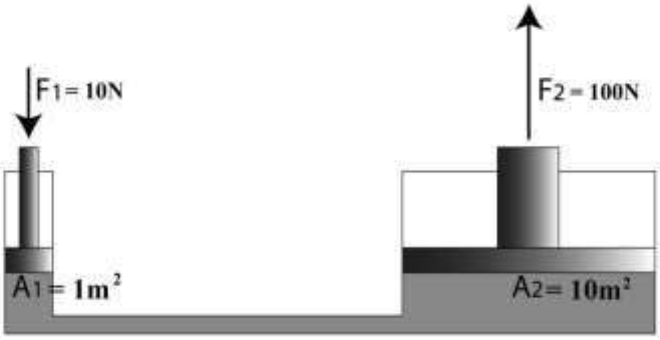
Hydrodynamic systems use fluid motion to transmit power. Power is transmitted by the kinetic energy of the fluid. Hydrodynamics deals with the mechanics of moving fluid and uses flow theory. The pump used in hydrodynamic systems is a non-positive displacement pump. An example of pure hydrodynamics is the conversion of flow energy in turbines in hydroelectric power plants.

In oil hydraulics, we deal mostly with the fluid working in a confined system, that is, a hydrostatic system.

PASCAL'S LAW (MULTIPLICATION OF FORCE):

Pascal's law reveals the basic principle of how fluid power systems perform useful work. This law can be stated as follows:

Pressure applied to a confined fluid is transmitted undiminished in all directions throughout the fluid and acts perpendicular to the surface in contact with the fluid.



The above figure shows how Pascal's law can be applied to produce a useful amplified output force. Consider an input force of 10N is applied to a 1-m^2 area piston. This develops a 10N/m^2 pressure throughout the oil within the housing. This 10N/m^2 pressure acts on a 10-m^2 area piston producing a 100N output force. This output force performs useful work as it lifts the 100N weight.

From Pascal's law we know that, $P_1 = P_2$ i.e., $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$$\frac{10}{1} = \frac{F_2}{10} \qquad \therefore F_2 = 100N$$

FLUIDS FOR HYDRAULIC SYSTEM:

The most important material in a hydraulic system is the working fluid itself. Hydraulic fluid characteristics have a crucial effect on equipment performance and life. It is important to use a clean, high-quality fluid in order to achieve efficient hydraulic system operation.

DIFFERENT TYPES OF HYDRAULIC FLUIDS:

1) Water: The least expensive hydraulic fluid is water. Water is treated with chemicals before being used in a fluid power system. This treatment removes undesirable contaminates.

2) Petroleum Oils: These are the most common among the hydraulic fluids which are used in a wide range of hydraulic applications. The characteristic of petroleum based hydraulic oils are controlled by the type of crude oil used.

3) Water Glycols: These are solutions contains 35 to 55% water, glycol and water soluble thickener to improve viscosity. Additives are also added to improve anticorrosion, anti-wear and lubricity properties.

4) Water Oil Emulsions**:** These are water-oil mixtures. They are of two types' oil-in-water emulsions or water-in-oil emulsions. The oil-in-water emulsion has water as the continuous base and the oil is present in lesser amounts as the dispersed media. In the water-in-oil emulsion, the oil is in continuous phase and water is the dispersed media.

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

PROPERTIES OF HYDRAULIC FLUIDS:

1) Viscosity: It is a measure of the fluid's internal resistance offered to flow.

2) Viscosity Index: This value shows how temperature affects the viscosity of oil. The viscosity of the oil decreases with increase in temperature and vice versa. The rate of change of viscosity with temperature is indicated on an arbitrary scale called viscosity index.

3) Oxidation Stability: The most important property of hydraulic oil is its oxidation stability. Oxidation is caused by a chemical reaction between the oxygen of the dissolved air and the oil. The oxidation of the oil creates impurities like sludge, insoluble gum and soluble acidic products. The soluble acidic products cause corrosion and insoluble products make the operation sluggish.

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

5) Lubricity: The ability of the hydraulic fluid to lubricate the moving parts efficiently is called Lubricity.

6) Rust Prevention: The moisture entering into the hydraulic system with air causes the parts made of ferrous materials to rust. This rust if passed through the precision made pumps and valves may scratch the nicely polished surfaces. So inhibitors are added to the oil to keep the moisture away from the surface.

7) Pour Point: The temperature at which oil will clot is referred to as the pour point i.e. the lowest temperature at which the oil is able to flow easily.

8) Flash Point and Fire Point: Flash point is the temperature at which a liquid gives off vapour in sufficient quantity to ignite momentarily or flash when a flame is applied. The minimum temperature at which the hydraulic fluid will catch fire and continue burning is called fire point.

9) Neutralization Number: The neutralization number is a measure of the acidity or alkalinity of a hydraulic fluid. This is referred to the PH value of the fluid. High acidity causes the oxidation rate in an oil to increase rapidly.

10) Density: It is that quantity of matter contained in unit volume of the substance.

11) Compressibility: All fluids are compressible to some extent. Compressibility of a liquid causes the liquid to act much like a stiff spring. The coefficient of compressibility is the fractional change in a unit volume of liquid per unit change of pressure.

SELECTION OF HYDRAULIC FLUIDS:

A hydraulic fluid has the following four primary functions:

1) Transmit Power

2) Lubricate moving parts

3) Seal clearances between mating parts

4) Dissipate heat

In addition a hydraulic fluid must be inexpensive and readily available. From the selection point of view, a hydraulic fluid should have the following properties:

1) Good lubricity

2) Ideal viscosity

3) Chemical stability

4) Compatibility with system materials

5) High degree of incompressibility

6) Fire resistance

7) Good heat-transfer capability

8) Low density

9) Foam resistance

10) Non-toxicity

11) Low volatility

This is a challenging list, and no single hydraulic fluid possesses all of these desirable characteristics. The fluid power designer must select the fluid that is the closest to being ideal overall for a particular application.

ADDITIVES:

Various additives are added to the fluid to sustain the important characteristics. Few such additives are:

1) Anti-foaming: They are added to reduce foaming of fluid.

2) Anti-wear: Wear resistant chemicals are added to the fluid to protect critical hydraulic components from wear.

3) Corrosion inhibitor: Chemicals are added to protect surfaces from chemical attack by water.

4) Biocide: Emulsifying chemicals are added to the fluid to inhibit growth of water-borne bacteria.

5) Emulsifier: These are added to facilitate formation and stabilisation of an emulsion.

6) Lubrication Oiliness agents: Extreme Pressure (EP) agents are added to the fluid to enhance lubrication characteristics for effective full film boundary lubrication between the mating parts.

7) Flocculants: Chemicals added to dispersion of solids in a liquid to combine fine particles to form floe or small solid masses in the fluid.

8) Deionisation: Elements which provide hardness like calcium, manganese, iron, and aluminium salts are removed through deionisation of the water.

9) Oxidation inhibitor: Anti-oxidation additives are added to provide anti-oxidation characteristics. Oxidation changes the chemical characteristics of the fluid.

10) Vapour phase inhibitor: Prevention of oxidation or corrosion of metals in contact with the vapour phase of the fluid is ensured by addition of appropriate chemicals.

EFFECT OF TEMPERATURE AND PRESSURE ON HYDRAULIC FLUID:

Viscosity is the most important property of a hydraulic fluid. Temperature has an adverse effect on the viscosity of hydraulic oil. Hence it has to be seen that the operating temperature of a hydraulic system is kept at a reasonably constant level. Otherwise there will be tremendous losses in the system which will reduce the overall efficiency.

A hydraulic fluid that is too viscous generates more friction and heat and usually causes high-pressure drop, sluggish operation, low-mechanical efficiency, and high-power consumption. On the other hand low-viscosity fluids permit efficient low-drag operation, but tend to increase wear, reduce volumetric efficiency, and promote leakage.

SEAL:

The seal is an agent which prevents leakage of oil from the hydraulic elements and protects the system from dust/dirt. The major function of the seal is to maintain pressure, prevent loss of fluid from the system and to keep out contamination in the system to enhance its working life and functional reliability over a longer period.

CLASSIFICATION OF SEALS:

According to the method of sealing:

1. Positive sealing: A positive seal prevents even a minute amount of oil from getting past. A positive seal does not allow any leakage whatsoever (external or internal).

2. Non-positive sealing: A non-positive seal allows a small amount of internal leakage, such as the clearance of the piston to provide a lubrication film.

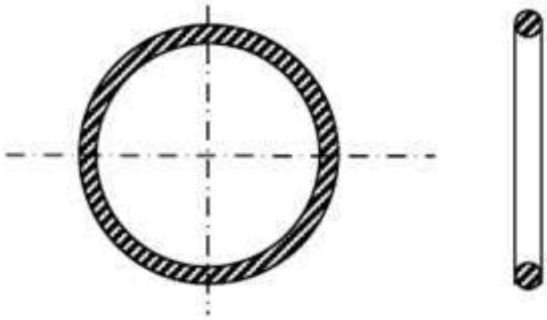
According to the relative motion existing between the seals and other parts:

1. Static seals: These are used between mating parts that do not move relative to one another. These are relatively simple. They are essentially non-wearing and usually trouble-free if assembled properly.

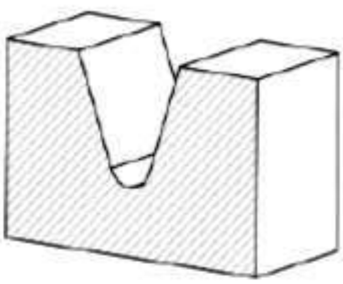
2. Dynamic seals: These are assembled between mating parts that move relative to each other. Hence, dynamic seals are subject to wear because one of the mating parts rubs against the seal.

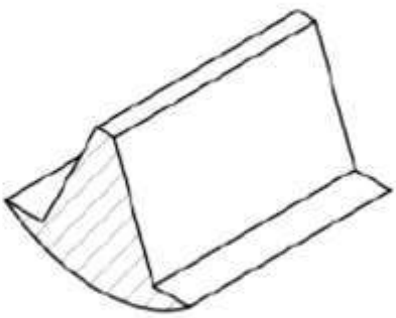
According to geometrical cross-section:

1. O-rings: O-ring is the most widely used seal for hydraulic systems. It is a moulded synthetic rubber seal that has a round cross-section in its free state. O-ring can be used for the most static and dynamic conditions. It gives effective sealing through a wide range of pressures, temperatures and movements.

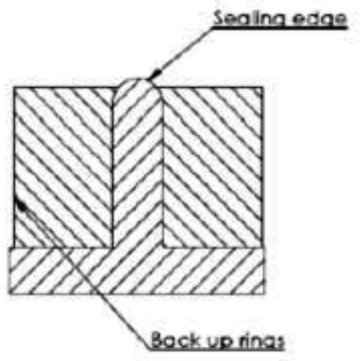


2. V-ring seal and U-ring seal: V- and U-ring seals are compression-type seals used in virtually all types of reciprocating motion applications. These include piston rods and piston seals in pneumatic and hydraulic cylinder, press rank, jacks and seals on plungers and piston in reciprocating pumps.





3. T-ring seal: T-ring seal is a dynamic seal that is extensively used to seal cylinder-pistons, piston rods and other reciprocating parts. It is made of synthetic rubber moulded in the shape of the cross-section T and reinforced by backup rings on either side. The sealing edge is rounded and seals very much like an O-ring.



4. Piston cup packings: Piston cup packings are designed specifically for pistons in reciprocating pumps and pneumatic and hydraulic cylinders. They offer the best service life for this type of application, require a minimum recess space and minimum recess machining, and can be installed easily and quickly.

5. Piston rings: Piston rings are seals that are universally used for cylinder pistons. Piston rings offer substantially less opposition to motion than synthetic rubber (elastomer) seals.

SEALING MATERIALS:

Various metallic and non-metallic materials are used for fabrication of seals that are used in hydraulic systems. Leather, metals and elastomers are very common seal materials.

1) Leather: This material is rugged and inexpensive. However, it tends to squeal (scream/screech) when dry and cannot operate above 90°C, which is inadequate for many hydraulic systems. Leather does operate well at cold temperatures to about -50°C.

2) Buna-N: This material is rugged and inexpensive and wears wells. It has a rather wide operating temperature range (-45°C to 110°C) during which it maintains its good sealing characteristics.

3) Silicone: This elastomer has an extremely wide operating temperature range (-65°C to 232°C). Hence it is widely used for rotating shaft seals and static seals. Silicone has low tear resistance and hence not used for reciprocating seal applications.

4) Neoprene**:** This material has a temperature range of 50°C to 120°C. it is unsuitable above 120°C because of its tendency to vulcanize.

5) Viton: This material contains 65% fluorine. It has become almost a standard material for elastomer-type seals for use at elevated temperatures up to 240°C. Its minimum operating temperature is 28°C.

6) Tetrafluoroethylene: This material is the most widely used plastic for seals of hydraulic systems. It is a tough, chemically inert, waxy solid, which can be processed only by compacting and sintering. It has excellent resistance to chemical breakdown up to temperatures of 370°C.

PIPES AND HOSES:

In a hydraulic system, the fluid flows through a distribution system consisting of pipes (conductors) and fittings, which carry the fluid from the reservoir through operating components and back to the reservoir.

Hydraulic systems use primarily four types of conductors:

1. Steel pipes

2. Steel tubing

3. Plastic tubing

4. Flexible Hoses

The choice of which type of conductor to use depends primarily on the system's operating pressures and flow-rates.

QUICK ACTING COUPLINGS:

Couplings are precision components, engineered for specific uses with exact dimensions and close tolerances. There are a variety of applications in modern industrial plants for quick connect (QC) couplings both for pneumatically operated tools as well as other fluid power equipments which can be connected rapidly to their power source to permit wide versatility for production needs. For instance, in connecting or disconnecting a tractor and its hydraulically actuated agricultural component.

QCs make changes simple, do not require additional hand tools, take little time and do not require the help of additional trade or skill. They are devices which permit the rapid connection or disconnection of fluid conductors.

FLUID CONDITIONING THROUGH FILTERS AND STRAINERS:

Hydraulic components are very sensitive to contamination. The cause of majority of hydraulic system failures can be traced back to contamination. Hence for proper operation and long service life of a hydraulic system, oil cleanliness is of prime importance. Strainers and filters are designed to remove foreign particles from the hydraulic fluid.

Filters are devices whose primary function is the retention of insoluble contaminants from fluid, by some fine porous medium. Filters are used to pick up smaller contaminant particles because they are able to accumulate them better than a strainer. Particle sizes removed by filters are measured in microns. The smallest sized particle that can be removed is as small as 1 μm.

A strainer is a coarse filter, whose function is to remove large particles from a fluid using a wire screen. Fluid flows more or less straight through it. It does not provide as fine a screening action as filters do, but offers less resistance to flow. The smallest sized particle that can be removed by a strainer is as small as 0.15 mm or 150 μm.

CLASSIFICATION OF FILTERS:

Based on filtering methods:

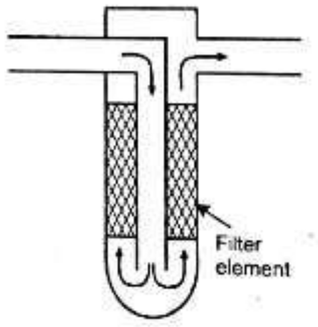
1. Mechanical: This type normally contains a metal or cloth screen or a series of metal disks separated by thin spacers. Mechanical filters are capable of removing only relatively coarse particles from the fluid.

2. Absorbent: These filters are porous and permeable materials such as paper, wood pulp, cloth, cellulose and asbestos. Paper filters are impregnated with a resin to provide added strength. In this type of filters, the particles are actually absorbed as the fluid infiltrates the material. Hence, these filters are used for extremely small particle filtration.

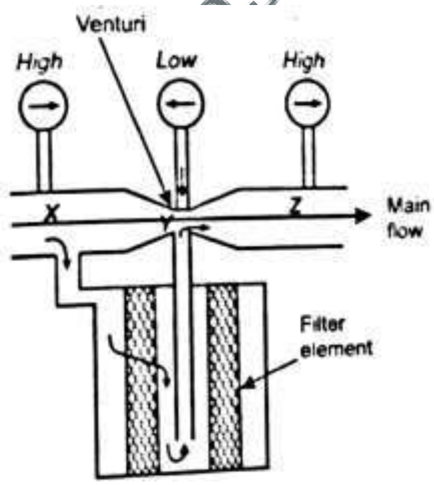
3. Adsorbent: Adsorption is a surface phenomenon and refers to the tendency of particles to cling to the surface of the filters. Thus, the capacity of such a filter depends on the amount of surface area available. Adsorbent materials used include activated clay and chemically treated paper.

Depending on the amount of oil filtered by a filter:

1. Full flow filters: In this type, complete oil is filtered. Full flow of oil must enter the filter element at its inlet and must be expelled through the outlet after crossing the filter element fully. This is an efficient filter. However, it incurs large pressure drops. This pressure drop increases as the filter gets blocked by contamination.



2. Proportional filters (bypass filters): In some hydraulic system applications, only a portion of oil is passed through the filter instead of entire volume and the main flow is directly passed without filtration through a restricted passage.



BETA RATIO OF FILTERS

Filters are rated according to the smallest size of particles they can trap. By mathematical definition, the beta ratio equals the number of upstream (before the filter) particles of size greater than Nμm divided by the number of downstream (after the filter) particles having size greater than Nμm. Where, N is the selected particle size for the given filter.

$$\text{Beta Ratio} = \frac{\text{No. of upstream particles of size} > \text{N}\mu\text{m}}{\text{No. of downstream particles of size} > \text{N}\mu\text{m}}$$

A beta ratio of 1 would mean that no particles above specified N are trapped by the filter. A beta ratio of 50 means that 50 particles are trapped for every one that gets through. Most filters have a beta ratio greater than 75.

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

$$\text{Beta Efficiency} = 1 - \frac{1}{\text{Beta Ratio}}$$

CAUSES OF CONTAMINATION:

1. Contaminants left in the system during assembly or subsequent maintenance work.

2. Contaminants generated when running the system such as wear particles, sludge and varnish due to fluid oxidation and rust and water due to condensation.

3. Contaminants introduced into the system from outside. These include using the wrong fluid when topping up and dirt particles introduced by contaminated tools or repaired components.

PROBLEMS CAUSED BY CONTAMINATION:

1. Accelerate component wear, decreasing system performance and service life.

2. Result in sluggish operation and cause moving parts to seize.

3. Damages seals resulting in leakage.

4. Act as a catalyst to accelerate hydraulic fluid oxidation and breakdown thereby shortening fluid life and reducing the useful operating temperature range of the fluid.

CONTAMINATION CONTROL:

There are many ways to reduce the effects of contaminants in a system.

1. Plumb the system with pipes, tubing and fittings that are reasonably free from rust, scale, dirt and other foreign matter.

2. Flush the entire hydraulic system, preferably with the same type of fluid to be used, before normal system operation is begun.

3. Filter the hydraulic oil before using, to minimise introducing contaminants into the system.

4. Provide continuous protection from airborne contamination by sealing the hydraulic system, or installing air filter/breather.

5. Clean or replace filter elements on a routine basis.

6. Maintain fluid viscosity and pH level within fluid suppliers' recommendations.

7. Minimise sources of water entry into the hydraulic system.

8. Avoid introducing thread sealants into the fluid stream.

HEAT EXCHANGERS:

The steady-state temperature of fluid of a hydraulic system depends on the heat-generation rate and the heat-dissipation rate of the system. If the fluid operating temperature in a hydraulic system becomes excessive, it means that the heat-generation rate is too large relative to the heat-dissipation rate. Assuming that the system is reasonably efficient, the solution is to increase the heat-dissipation rate. This is accomplished by the use of coolers, which are commonly called "heat exchangers."

In some applications, the fluid must be heated to produce a satisfactory value of viscosity. This is typical when, for example, mobile hydraulic equipment is to operate below 0°C. In these cases, the heat exchangers are called "heaters." However, for most hydraulic systems, the natural heat-generation rate is sufficient to produce high enough temperatures after an initial warm-up period.

Basically, there are two types of heat exchangers: Air cooled heat exchangers and Water cooled heat exchangers. Air coolers are used where water is not readily available and the air is at least 3° to 5°C cooler than the oil. But water coolers are more compact, reliable, and efficient and use simple temperature controls.

QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS:

DEC 2015/JAN 2016

1) With a neat sketch, explain the hydraulic circuit and laws plugged to develop the circuit.

2) What are the various functions performed by the hydraulic fluid and list its desirable properties and types of hydraulic fluid.

3) Explain Beta ratio and Beta efficiency.

4) Explain the common location of mounting filters in the hydraulic system.

JUNE/JULY 2016

1) Sketch and explain structure of a hydraulic control system.

2) What are the desirable properties of hydraulic oil? Explain them.

3) Sketch and explain full flow filter.

DEC 2016/JAN 2017

1) State Pascal's law. Explain its applications, with a neat sketch.

2) How are hydraulic seals classified? Explain positive and non-positive seals.

3) With the aid of sketches, explain the following: i) Return line filtering ii) Suction line filtering iii) Pressure line filtering

JUNE/JULY 2017

1) State Pascal's law. With a neat sketch explain basic hydraulic power system.

2) What are the desirable properties of hydraulic fluids? Explain briefly.

3) How hydraulic seals are classified? Explain any one method.

4) What is a filter? What are the methods of filtering? Explain briefly.

DEC 2017/JAN 2018

1) With a neat block diagram, explain the structure of hydraulic power system.

2) What are the advantages of hydraulic system?

3) Write any five desirable properties of a hydraulic fluid.

4) Explain three basic types of filtering methods used in hydraulic system.

5) Explain static seals and dynamic seals with examples.

JUNE/JULY 2018

1) State Pascal’s law.

2) What is seal and what are its functions? Explain sealing devices used in hydraulic systems.

3) What is a filter and how they are classified?

ONE TIME EXIT SCHEME – APRIL 2018

1) Define hydraulic system. What are its advantages and disadvantages?

2) Draw a structure of hydraulic system and explain the parts.

3) For a simple hydraulic jack the following data is given. F_1 = 100N, A_1 = 50cm^2, S_1 = 10cm Find load F_2 and displacement S_2 if area of piston that to be lifted is 500cm^2. Also find energy input and energy output.

4) What are the desirable properties of hydraulic oils?

5) Sketch and explain different filtering systems in a circuit.

MODULE 2: PUMPS AND ACTUATORS

Pumps: Classification of pumps, pumping theory of positive displacement pumps, construction and working of Gear pumps, Vane pumps, Piston pumps, fixed and variable displacement pumps, Pump performance characteristics, pump selection factors, problems on pumps.

Accumulators: Types, selection/ design procedure, applications of accumulators. Types of Intensifiers, Pressure switches /sensor, Temperature switches/sensor, Level sensor.

Actuators: Classification cylinder and hydraulic motors, Hydraulic cylinders, single and double acting cylinder, mounting arrangements, cushioning, special types of cylinders, problems on cylinders. Construction and working of rotary actuators such as gear, vane, piston motors, and Hydraulic Motor. Theoretical torque, power, flow rate, and hydraulic motor performance; numerical problems. Symbolic representation of hydraulic actuators (cylinders and motors).

PUMPS

A pump, which is the heart of hydraulic system, converts mechanical energy into hydraulic energy. The mechanical energy is delivered to the pump using a prime mover such as an electric motor. Due to the mechanical action, the pump creates a partial vaccum at its inlet. This permits atmospheric pressure to force the fluid through the inlet line and into the pump. The pump then pushes the fluid into the hydraulic system.

CLASSIFICATION OF PUMPS:

Pumps are broadly classified into two types

1) Dynamic (non-positive displacement) pumps

2) Positive displacement pumps

1) Dynamic (non-positive displacement) pumps: This type is generally used for low-pressure, high-volume flow applications. Because they are not capable of withstanding high pressures, they are of little use in the fluid power field. Normally their maximum pressure capacity is limited to 250-300psi. This type of pump is primarily used for transporting fluids from one location to another. The two most common types of dynamic pumps are the centrifugal and axial flow propeller pumps.

2) Positive displacement pumps: This type is universally used for fluid power systems. As the name implies, a positive displacement pump ejects a fixed amount of fluid into the hydraulic system per revolution of pump shaft rotation. Such a pump is capable of overcoming the pressure resulting from the mechanical loads on the system as well as the resistance to flow due to friction.

Positive displacement pumps are further classified into:

i) Fixed displacement pumps: It is the one in which the amount of fluid ejected per revolution (displacement) cannot be varied.

ii) Variable displacement pumps: In this type of pumps, the displacement can be varied by changing the physical relationships of various pump elements. This change in pump displacement produces a change in pump flow output even though pump speed remains constant.

The advantages of positive displacement pumps over non-positive displacement pumps are as follows:

1. They can operate at very high pressures of up to 800 bar (used for lifting oils from very deep oil wells).

2. They can achieve a high volumetric efficiency of up to 98%.

3. They are highly efficient and almost constant throughout the designed pressure range.

4. They are a compact unit, having a high power-to-weight ratio.

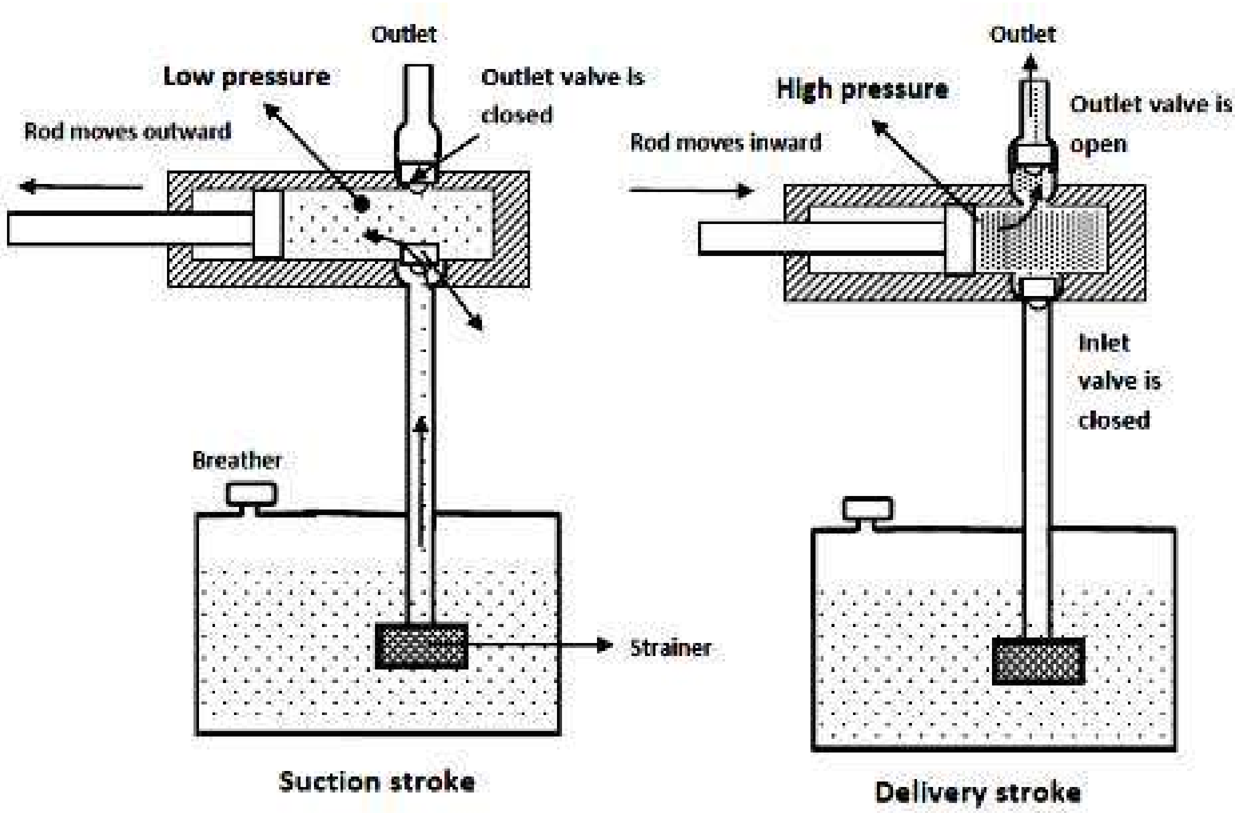
5. They can obtain a smooth and precisely controlled motion.

6. By proper application and control, they produce only the amount of flow required to move the load at the desired velocity.

7. They have a great flexibility of performance. They can be made to operate over a wide range of pressures and speeds.

PUMPING THEORY OF POSITIVE DISPLACEMENT PUMPS:

Pumps operate on the principle whereby a partial vaccum is created at the pump inlet due to the internal operation of the pump. This allows atmospheric pressure to push the fluid out of oil tank (reservoir) and into the pump intake. The pump then mechanically pushes the fluid out the discharge line. This action can be best described by reference to a simple piston pump shown in Fig.



1. As the piston moves to the left, a partial vacuum is created in the pump chamber that holds the outlet valve in place against its seat and induces flow from the reservoir that is at a higher (atmospheric) pressure. As this flow is produced, the inlet valve is temporarily displaced by the force of fluid, permitting the flow into the pump chamber (suction stroke).

2. When the piston moves to the right, the resistance at the valves causes an immediate increase in the pressure that forces the inlet valve against its seat and opens the outlet valve thereby permitting the fluid to flow into the system. If the outlet port opens directly to the atmosphere, the only pressure developed is the one required to open the outlet valve (delivery stroke).

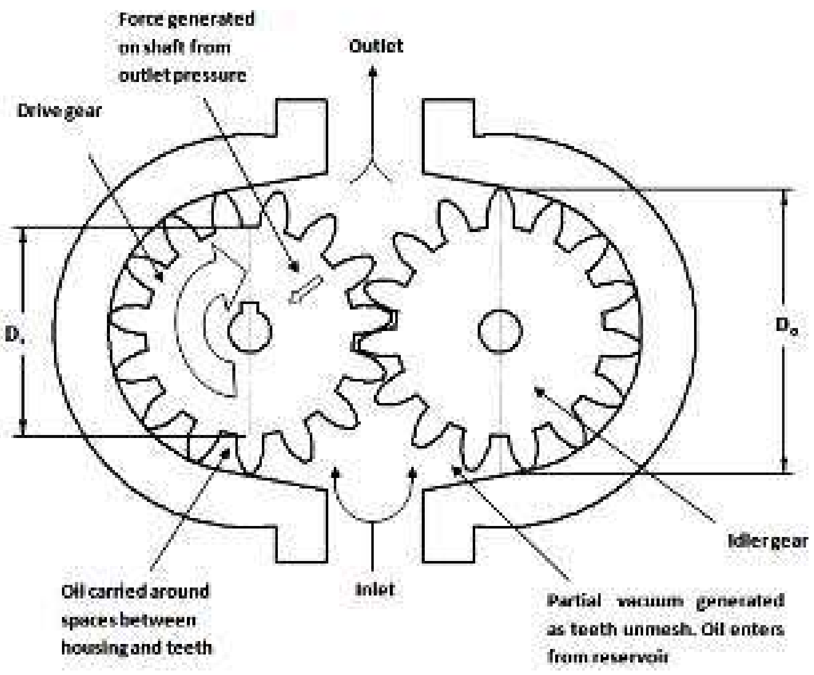
CLASSIFICATION OF POSITIVE DISPLACEMENT PUMPS:

1. **Gear Pumps**
   - External Gear pump
   - Internal Gear pump
2. **Vane Pumps**
   - Balanced vane pump
   - Unbalanced vane pump
3. **Piston Pumps**
   - Axial type
   - Radial type

GEAR PUMPS:

Gear pumps are less expensive but limited to low pressures. It is noisy in operation than either vane or piston pumps. Gear pumps are invariably of fixed displacement type, which means that the amount of fluid displaced for each revolution of the drive shaft is theoretically constant.

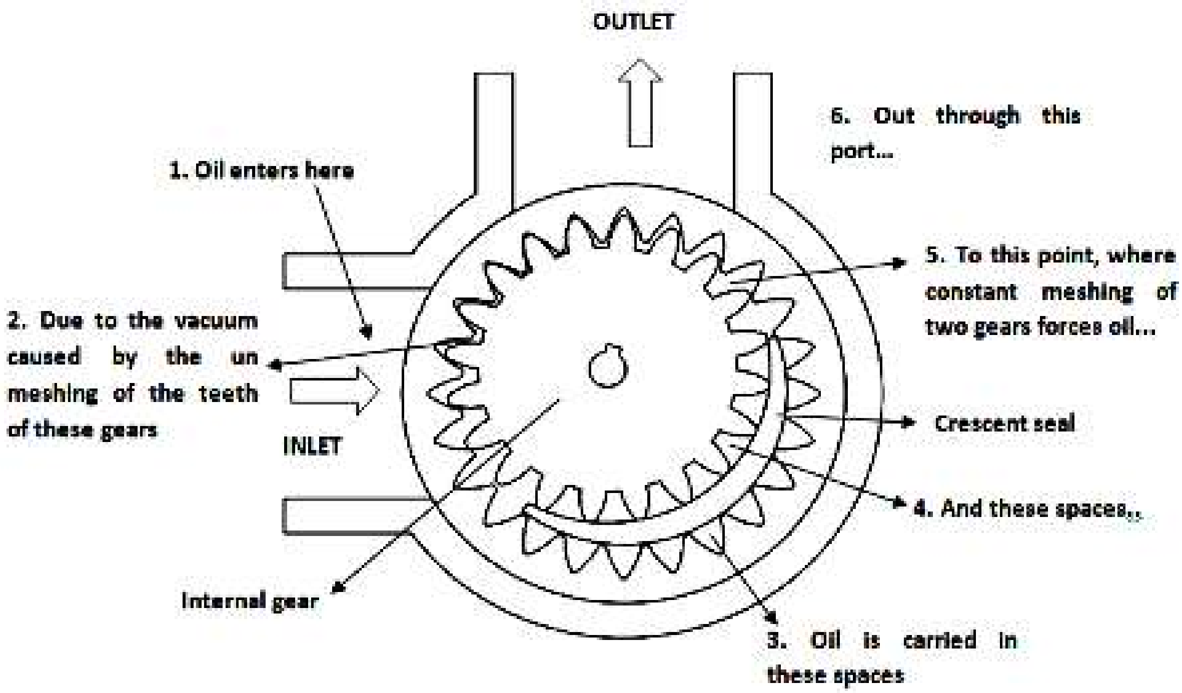
EXTERNAL GEAR PUMPS:



External gear pumps are the most popular hydraulic pumps in low-pressure ranges due to their long operating life, high efficiency and low cost. They are generally used in a simple machine. The external gear pump consists of a pump housing in which a pair of precisely machined meshing gears runs with minimal radial and axial clearance. One of the gears, called a driver, is driven by a prime mover. The driver drives another gear called a follower. As the teeth of the two gears separate, the fluid from the pump inlet gets trapped between the rotating gear cavities and pump housing. The trapped fluid is then carried around the periphery of the pump casing and delivered to outlet port. The teeth of precisely meshed gears provide almost a perfect seal between the pump inlet and the pump outlet.

INTERNAL GEAR PUMPS:

Internal Gear Pumps consist of two gears: An external gear and an internal gear. The crescent placed in between these acts as a seal between the suction and discharge. When a pump operates, the internal gear drives the external gear and both gears rotate in the same direction. The fluid fills the cavities formed by the rotating teeth and the stationary crescent. Both the gears transport the fluid through the pump. The crescent seals the low-pressure pump inlet from the high-pressure pump outlet. These pumps have a higher pressure capability than external gear pumps.



ADVANTAGES OF GEAR PUMPS:

1.They are self-priming.

2.They give constant delivery for a given speed.

3. They are compact and light in weight.

DISADVANTAGES OF GEAR PUMPS:

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

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

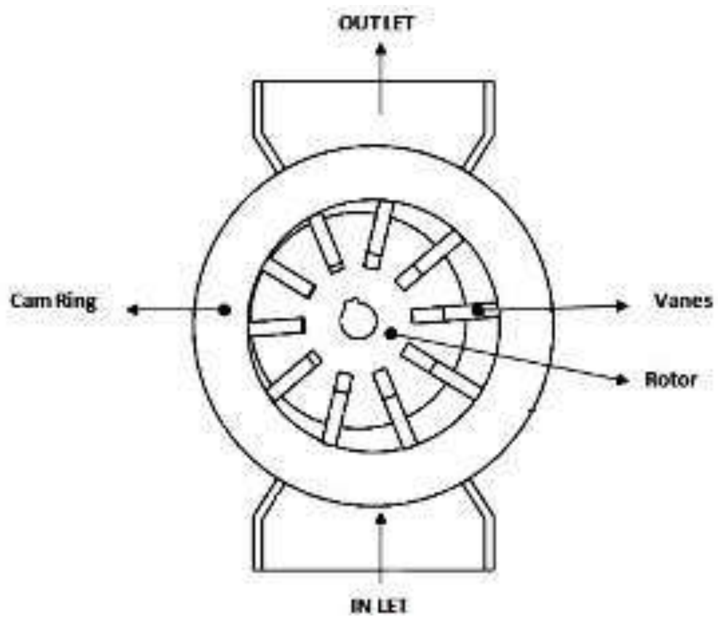
3. If they run dry, parts can be damaged because the fluid to be pumped is used as lubricant.

VANE PUMPS:

Vane Pumps are classified into

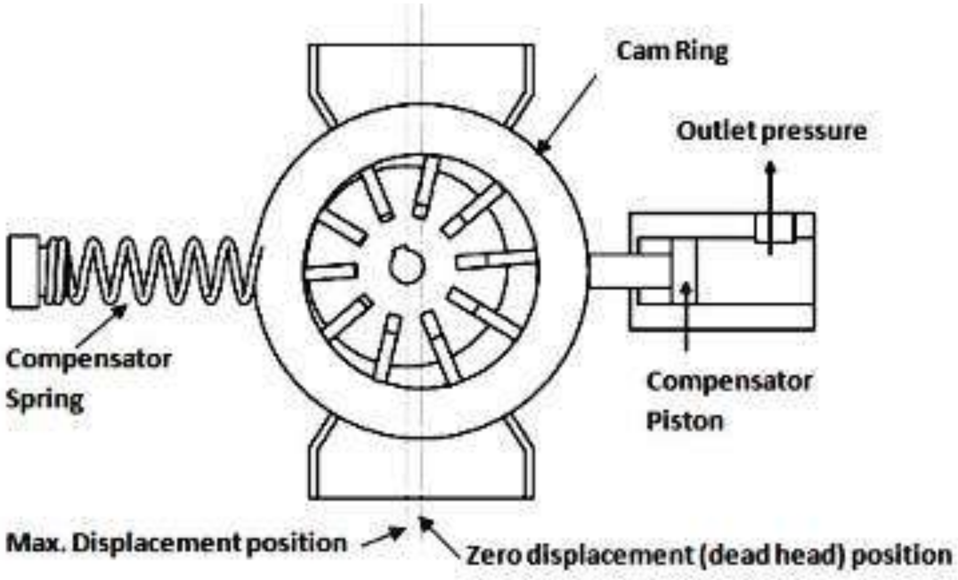
1. **Unbalanced vane pump**
    - Fixed displacement type
    - Pressure compensated variable displacement type
2. **Balanced vane pump**

UNBALANCED FIXED DISPLACEMENT VANE PUMP:



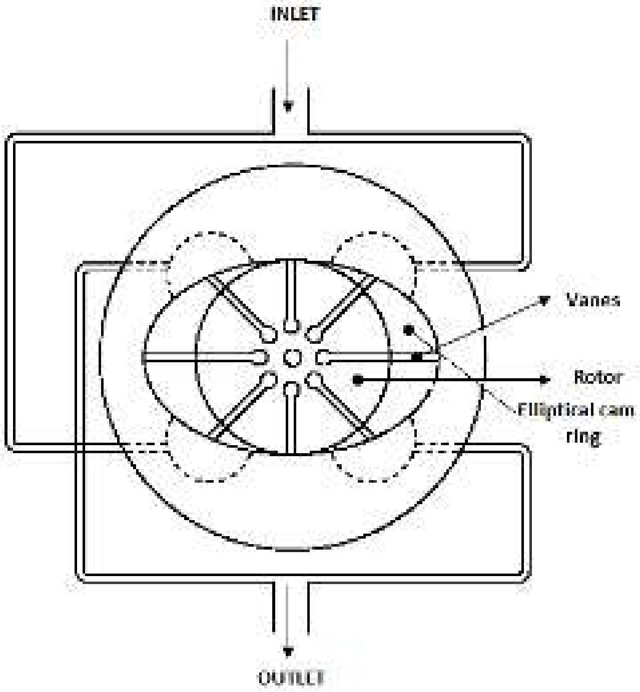
The main components of the pump are the cam surface and the rotor. The rotor contains radial slots splined to drive shaft. The rotor rotates inside the cam ring. Each radial slot contains a vane, which is free to slide in or out of the slots due to centrifugal force. The cam ring axis is offset to the drive shaft axis. When the rotor rotates, the centrifugal force pushes the vanes out against the surface of the cam ring. The vanes divide the space between the rotor and the cam ring into a series of small chambers. During the first half of the rotor rotation, the volume of these chambers increases, thereby causing a reduction of pressure. This is the suction process, which causes the fluid 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 positively ejects the trapped fluid through the outlet port. The delivery rate of the pump depends on the eccentricity of the rotor with respect to the cam ring.

UNBALANCED PRESSURE COMPENSATED VARIABLE DISPLACEMENT VANE PUMP:



Variable displacement feature can be brought into vane pumps by varying eccentricity between the rotor and the cam ring. Here in this pump, the stator ring is held against a spring loaded piston. The system pressure acts directly through a hydraulic piston on the right side. This forces the cam ring against a spring-loaded piston on the left side. If the discharge pressure is large enough, it overcomes the compensated spring force and shifts the cam ring to the left. This reduces the eccentricity and decreases the flow. If the pressure continues to increase, there is no eccentricity and pump flow becomes zero.

BALANCED VANE PUMP:



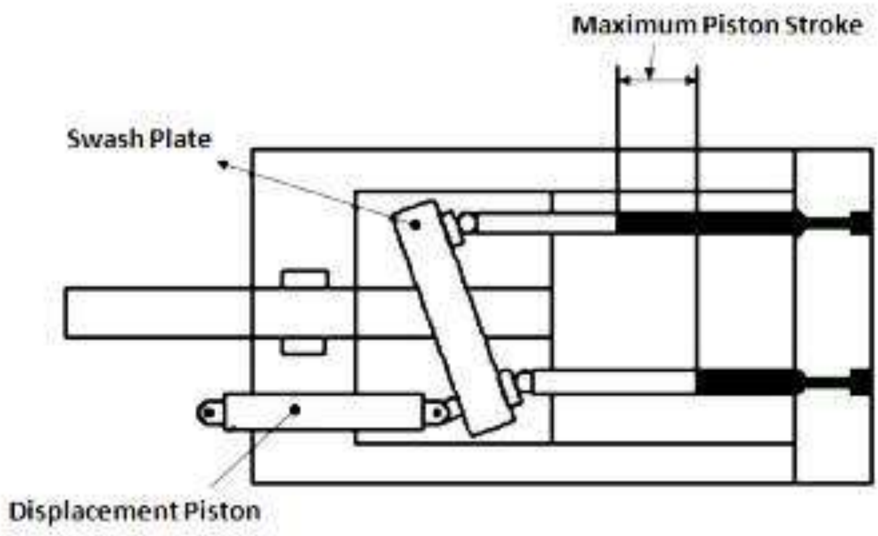
The constructional features of a balanced vane pump is as shown in the fig. The rotor and the casing are on the same centre line. Vanes are provided in the slots of the rotor. There are two inlet and outlet chambers around the elliptical cam ring surface. The inlet and outlet chambers are positioned diagonally opposite to each other. The cam ring is elliptical in shape, so that the vanes stroke twice per revolution of the pump shaft. Thus the volume increase and decrease at the inlet and outlet chambers also occur twice per revolution. In fact, the inlet and outlet ports are connected to a common inlet and outlet within the pump housing. In operation, due to the elliptical shape of the cam ring, the oil suction at the inlets and the pumping at the outlets occurs simultaneously. This situation results in equal pressure on the opposite sides of the pump shaft, and the net force acting on bearing will be zero. Thus, it is termed the balanced vane pump.

PISTON PUMPS:

Piston pumps are of following types

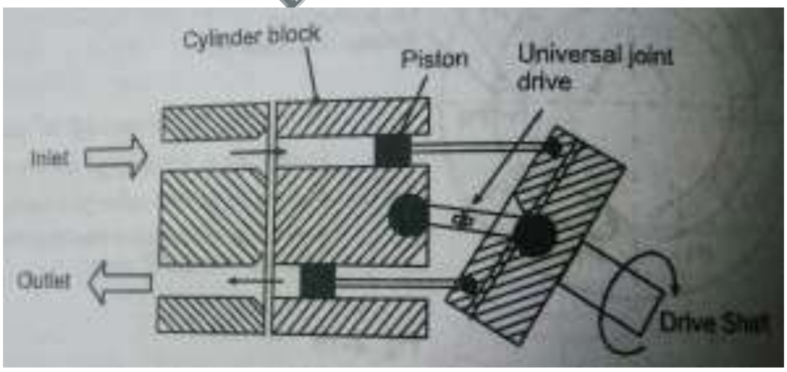
1. **Axial Piston Pump**
   - Swash plate type piston pump
   - Bent axis type piston pump
2. **Radial Piston Pump**

SWASH PLATE TYPE PISTON PUMP:



In this type, the cylinder block and drive shaft are located on the same center line. The pistons are connected to a shoe plate that bears against an angled swash plate. As the cylinder rotates, the pistons reciprocate because the piston shoes follow the angled surface of the swash plate. The outlet and inlet ports are located in the valve plate so that the pistons pass the inlet as they are being pulled out and pass the outlet as they are being forced back in. This type of pump can also be designed to have a variable displacement capability.

BENT AXIS TYPE PISTON PUMP:



In constryction it consists of a cylinder block with arrayed cylindrical openings, housing, pistons and drive shaft. The housing design is such that it creates an offset angle between the centreline of the drive shaft and the centre line of the cylinder block. The pistons are connected to the drive plate with ball and socket joints. The drive plate and the cylinder block are connected with an universal joint, so that the motion is transmitted through the bent axis. The bent axis of the drive shaft leads to the reciprocatory motion of the pistons in the cylinder block. The housing end at the cylinder block is sealed with an end cap, having inlet and outlet ports with feed grooves.

PUMP PERFORMANCE:

The performance of a pump is a function of the precision of its manufacture. An ideal pump is one having zero clearance between all mating parts. Since this is not possible, working clearances should be as small as possible while maintaining proper oil films for lubrication between rubbing parts. The performance of a pump is determined by the following efficiencies:

1) **Volumetric efficiency (η_v):** It is the ratio of actual flow rate of the pump to the theoretical flow rate of the pump.

$$\eta_v = \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}} \times 100$$
$$= \frac{Q_A}{Q_T} \times 100$$

2) **Mechanical Efficiency (η_m):** It refers to the efficiency of the pump due to energy losses other than due to leakages.

$$\eta_m = \frac{\text{Pump output power (no leakage condition)}}{\text{Actual power input to pump}} \times 100$$
$$= \frac{P \times Q_T}{2\pi NT} \times 100$$

Where, P = Pump discharge pressure, Pa

QT = Theoretical flow rate, m3/s

T = Torque input to pump, N.m

N = Pump speed, rps

3) **Overall Efficiency (η_o):** Overall efficiency refers to the overall performance of the pump considering possible losses including the leakage loss, friction loss, etc. it is given by the relation:

$$\eta_o = \frac{\text{Actual power output by pump}}{\text{Actual power input to pump}} \times 100$$

It can also be given by,

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

$$\eta_o = \frac{P \times Q_A}{2\pi NT} \times 100$$

PUMP SELECTION FACTORS:

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

1) Maximum operating pressure.
2) Maximum delivery.
3) Type of control.
4) Pump drive speed.
5) Type of fluid.
6) Pump contamination tolerance.
7) Pump noise.
8) Size and weight of a pump.
9) Pump efficiency.
10) Cost.
11) Availability and interchangeability.
12) Maintenance and Spares.

ACCUMULATORS:

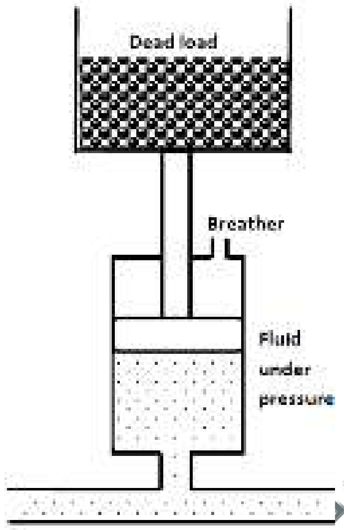
A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source. The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work.

CLASSIFICATION OF HYDRAULIC ACCUMULATORS:

1) Weight loaded or gravity accumulator
2) Spring-loaded accumulator
3) Gas-loaded accumulator
   a) Non-seperator type

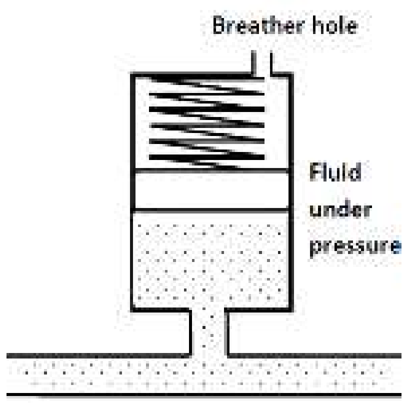
b) Seperator type
   i) Piston type
   ii) Diaphragm type
   iii) Bladder type

WEIGHT LOADED OR GRAVITY ACCUMULATOR:



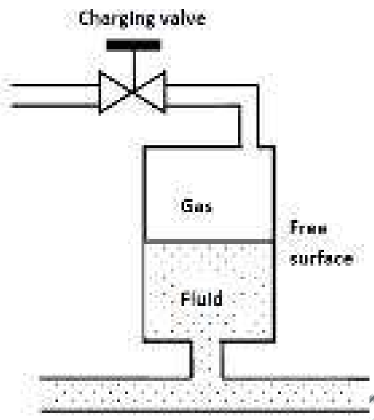
It is a vertically mounted cylinder with a large weight. When the hydraulic fluid is pumped into it, the weight is raised. The weight applies a force on the piston that generates a pressure on the fluid side of piston. The advantage of this type of accumulator over other types is that it applies a constant pressure on the fluid throughout its range of motion. The main disadvantage is its extremely large size and heavy weight. This makes it unsuitable for mobile application.

SPRING LOADED ACCUMULATOR:



A spring-loaded accumulator stores energy in the form of a compressed spring. A hydraulic fluid is pumped into the accumulator, causing the piston to move up and compress the spring. The compressed spring then applies a force on the piston that exerts a pressure on the hydraulic fluid. This type of accumulator delivers only a small volume of oil at relatively low pressure.

GAS LOADED ACCUMULATOR:



A gas-loaded accumulator is popularly used in industries. Here the force is applied to the oil using compressed air. A gas accumulator can be very large and is often used with water or high water-based fluids using air as a gas charge.

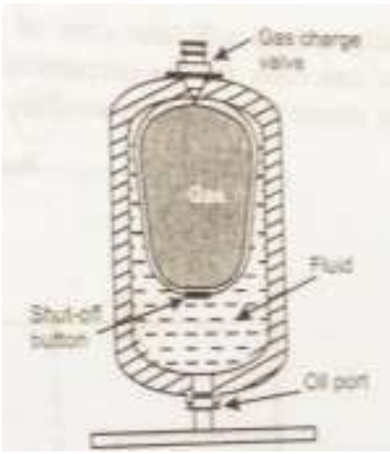
There are two types of gas-loaded accumulators:

- **Non-separator-type accumulator:** Here the oil and gas are not separated. Hence, they are always placed vertically.
- **Separator-type accumulator:** Here the oil and gas are separated by an element. Based on the type of element used to separate the oil and gas, they are classified as follows:

a) **Piston type accumulator:** It consists of a cylinder with a freely floating piston with proper seals. Its operation begins by charging the gas chamber with a gas (nitrogen) under a pre-determined pressure. This causes the free sliding piston to move down. Once the accumulator is pre-charged, a hydraulic fluid can be pumped into the hydraulic fluid port. As the fluid enters the accumulator, it causes the piston to slide up, thereby compressing the gas that increases its pressure and this pressure is then applied to the hydraulic fluid through the piston.

b) **Diaphragm type accumulator:** In this type, the hydraulic fluid and nitrogen gas are separated by a synthetic rubber diaphragm. The advantage of a diaphragm accumulator over a piston accumulator is that it has no sliding surface that requires lubrication and can therefore be used with fluids having poor lubricating qualities. It is less sensitive to contamination due to lack of any close-fitting components.

c) **Bladder type accumulator:** Here the gas and the hydraulic fluid are separated by a synthetic rubber bladder. The bladder is filled with nitrogen until the designed pre-charge pressure is achieved. The hydraulic fluid is then pumped into the accumulator, thereby compressing the gas and increasing the pressure in the accumulator.



ACTUATORS:

An actuator is used to convert the energy of fluid back into the mechanical power. The amount of output power developed depends upon the flow rate, the pressure drop across the actuator and its overall efficiency. Thus, hydraulic actuators are devices used to convert pressure energy of the fluid into mechanical energy.

Depending on the type of actuation, hydraulic actuators are classified as follows:

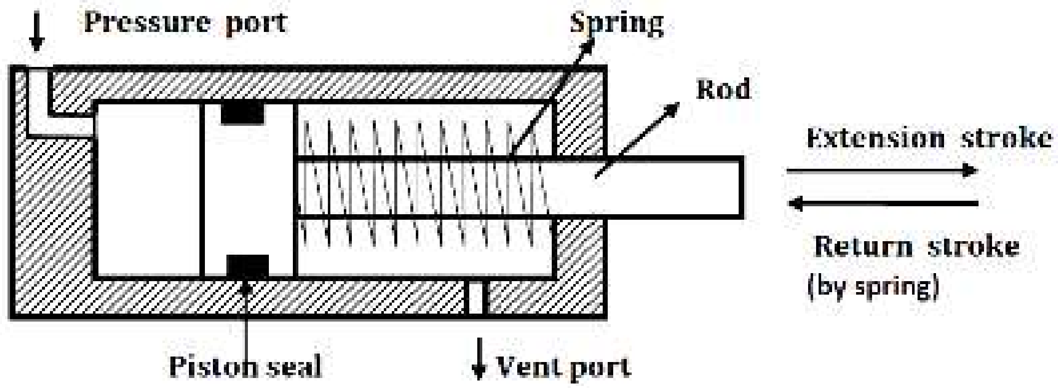
1) **Linear actuator**: For linear actuation (hydraulic cylinders)
2) **Rotary actuator:** For rotary actuation (hydraulic motor)

Hydraulic linear actuators, as their name implies, provide motion in a straight line. They are usually referred to as cylinders, rams and jacks. The function of hydraulic cylinder is to convert hydraulic power into linear mechanical force or motion. Hydraulic cylinders extend and retract a piston rod to provide a push or pull force to drive the external load along a straight-line path.

Hydraulic cylinders are of the following types:

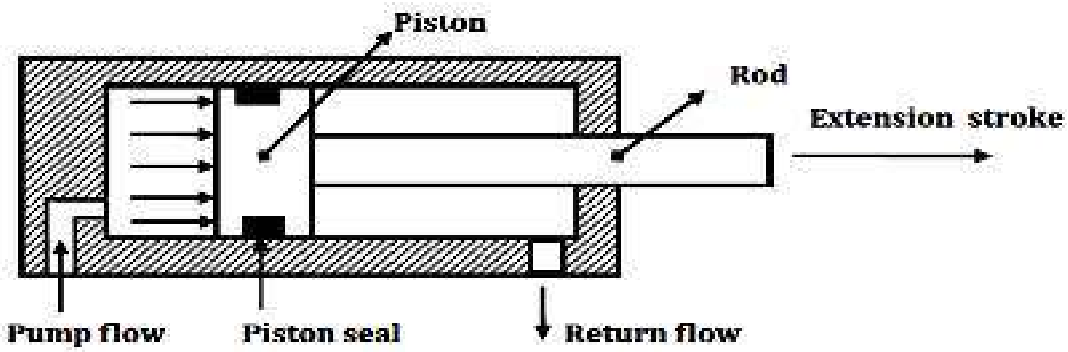
- Single-acting cylinders
- Double-acting cylinders
- Double rod cylinders
- Tandem cylinders
- Telescopic cylinders
- Cushioned cylinders

SINGLE-ACTING CYLINDERS:

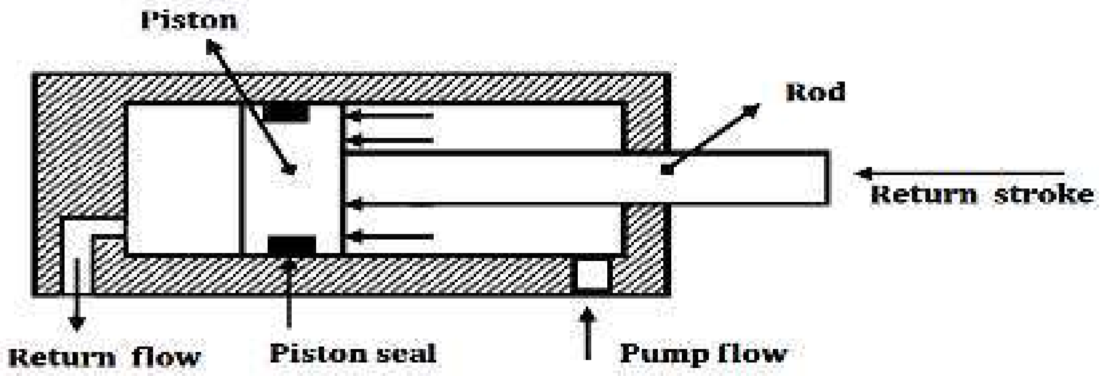


A single-acting cylinder is simplest in design and consists of a piston inside a cylindrical housing called barrel. On one end of the piston there is a rod, which can reciprocate. At the opposite end, there is a port for the entrance and exit of oil. Single-acting cylinders produce force in one direction by hydraulic pressure acting on the piston during extension stroke. The retraction is done either by gravity or by a spring.

DOUBLE ACTING CYLINDERS:



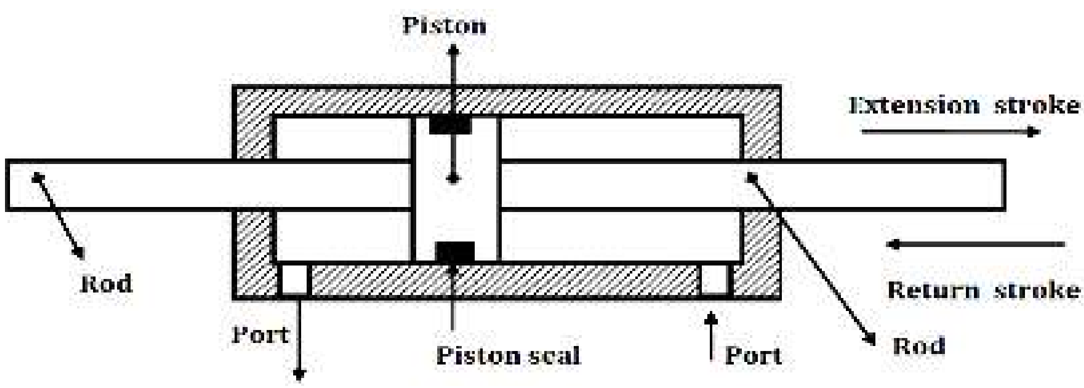
(a)



(b)

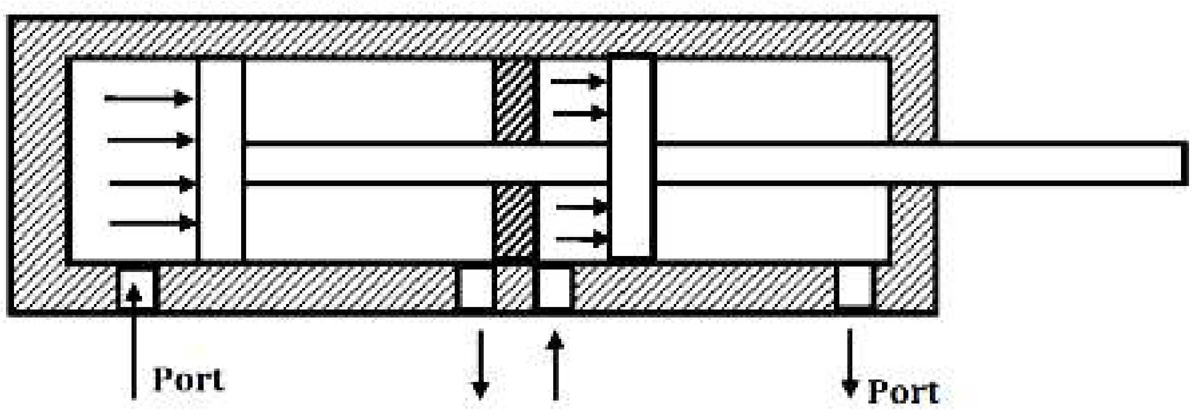
Figure shows the operation of a double-acting cylinder with a piston rod on one side. To extend the cylinder, the pump flow is sent to the blank-end port as in Fig.(a). The fluid from the rod-end port returns to the reservoir. To retract the cylinder, the pump flow is sent to the rod-end port and the fluid from the blank-end port returns to the tank as in Fig.(b).

DOUBLE ROD CYLINDERS:



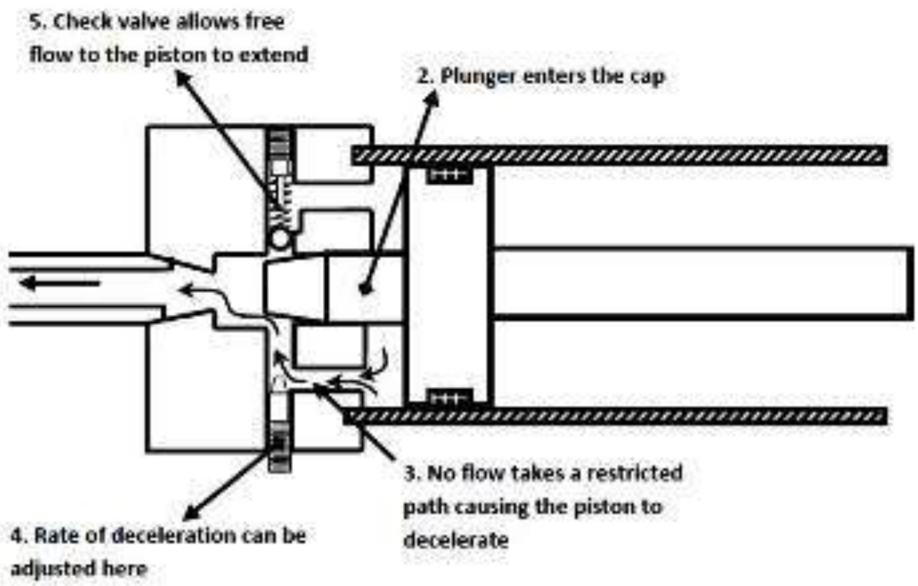
A double-acting cylinder with a piston rod on both sides is a cylinder with a rod extending from both ends. This cylinder can be used in an application where work can be done by both ends of the cylinder, thereby making the cylinder more productive. Double-rod cylinders can withstand higher side loads because they have an extra bearing, one on each rod, to withstand the loading.

TANDEM CYLINDERS:



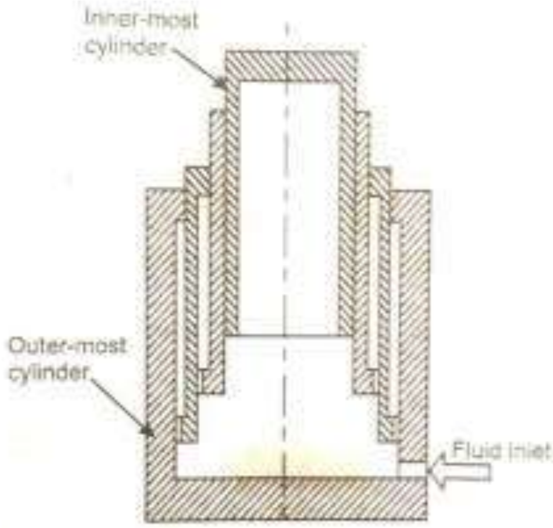
A tandem cylinder is used in applications where a large amount of force is required from a small-diameter cylinder. Pressure is applied to both pistons, resulting in increased force because of the larger area. The drawback is that these cylinders must be longer than a standard cylinder to achieve an equal speed because flow must go to both pistons.

CUSHIONED CYLINDERS:



When the cylinder piston is actuated, the fluid enters the cylinder port and flows through the little check valve so that the entire piston area can be utilized to produce force and motion. For the prevention of shock due to stopping loads at the end of the piston stroke, cushion devices are used. Cushions may be applied at either end or both ends. They operate on the principle that as the cylinder piston approaches the end of stroke, an exhaust fluid is forced to go through an adjustable needle valve that is set to control the escaping fluid at a given rate. This allows the deceleration characteristics to be adjusted for different loads.

TELESCOPIC CYINDERS:



It has multiple cylinders that are mounted concentrically one within the other. The design is such that the inner most cylinder extends first, while the next cylinder extends after completion of the full stroke of the cylinder. Thus, each cylinder extends in stage, one after the other. Each stage of the cylinder has a sleeve that fits into the previous stage of the cylinder. The total stroke length achieved will be sum of the strokes of all the stages.

QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS:

DEC 2015/JAN 2016

1) Explain the working and design of a vane pump.
2) A pump has a displacement volume of 120cm^3. It delivers 1.5×10^{-3} m^3/s at 1440RPM and 60bar. If the prime mover input torque is 130 N-m and overall efficiency 88%, find theoretical discharge of the pump, volumetric efficiency of the pump, mechanical effieciency of the pump, overall efficiency.
3) A pump supplies oil at 0.0016 m^3/s at a 40mm diameter double acting hydraulic cylinder. If the load is 500N and the rod dia is 20mm, find i) cylinder power during extension stroke ii) cylinder power during retraction stroke iii) pressure during extension and retraction stroke iv) piston velocity during extension and retraction stroke.

JUNE/JULY 2016

1) Explain the construction and working of an external gear pump.
2) Determine the volumetric efficiency of a gear pump of external diameter and internal diameter of gears 75mm and 50mm respectively and width of gear teeth 50mm, if the actual discharge is 30LPM at 1800rpm. [LPM = Litres per minute]
3) Sketch and explain double acting cylinder.

DEC 2016/JAN 2017

1) Explain the working of unbalanced vane pump. Also obtain an expression for its theoretical discharge.
2) A pump having a displacement of 25cm^3, operates with a pressure of 250bar and speed of 1390rpm. Volumetric efficiency of 0.85 and mechanical efficiency of 0.80. calculate i) pump delivery in LPM ii) input power at pimp shaft in KW iii) Drive Torque at pump shaft
3) An 8cm diameter hydraulic cylinder has 4cm diameter rod. If the cylinder receives the flow at 100LPM and 12Mpa. Find i) extension and retraction speeds ii) extension and retraction load carrying capacities.

JUNE/JULY 2017

1) With neat sketch explain the construction and working of a gear pump.
2) Determine the volumetric efficiency of a gear pump of external and internal diameters 75mm and 50mm respectively. Width of the gear teeth is 50mm. if the actual discharge is 30×10^{-3} m^3/min at 1800rpm.
3) With a neat sketch explain the working of linear actuator for single acting cylinder.

DEC 2017/JAN 2018

1) A gear pump has a 75mm outside diameter, a 50mm inside diameter and a 25mm width. If the volumetric efficiency is 90% at rated pressure, what is the corresponding actual flow rate? The pump speed is 1000rpm.
2) A pump has a displacement volume of 100 cm^3. It delivers 0.0015 m^3/s at 1000rpm and 70bars. If the prime mover input torque is 120N-m. Determine
   i) What is the overall efficiency of the pump?
   ii) What is the theoretical torque required to operate the pump?
3) A pump supplies oil at 75.8 litres/min to a 50.8mm diameter double-acting hydraulic cylinder. If the load is 4448 N (extending and retracting) and the rod diameter is 25.4mm, find
   i) The hydraulic pressure during the extension and retraction stroke
   ii) The piston velocity during the extension and retraction stroke
   iii) The cylinder power during extension and retraction stroke
4) Explain with a neat sketch a Gear Pump.

JUNE/JULY 2018

1) With a neat diagram, explain the working principle of a typical hydraulic gear pump.
2) What is actuator? State its broad classification.
3) Explain the following single acting cylinders with neat sketches.
   i) Gravity Type ii) Spring Type iii) Telescopic iv) Tandem

CRASH COURSE – MAY 2017

1) What is the pressure compensated vane pump? How does it work? Explain with neat sketch.

2) A pump supplies oil at 0.0016m^3/s to a 40mm double acting hydraulic cylinder. If the load is 5000N (extending and retracted) and the rod diameter is 20mm, find the hydraulic pressure during extension and retraction stroke, piston velocity during extension and retraction stroke, cylinder power during the extension and retraction stroke.

ONE TIME EXIT SCHEME – APRIL 2018

1) Give the classification of pumps. With a neat sketch explain swash plate type piston pump.
2) A pump has a displacement of 98.4cm^3. It delivers 0.00152 m^3/s of oil at 1000rpm and 70bar. If the prime mover input torque is 124.3N-m. Find i) Overall efficiency of pump; ii) theoretical torque required to operate the pump.
3) With a neat sketch, explain external gear pump.

MODULE 3: COMPONENTS AND HYDRAULIC CIRCUIT DESIGN

Components: Classification of control valves, Directional Control Valves-symbolic representation, constructional features of poppet, sliding spool, rotary type valves solenoid and pilot operated DCV, shuttle valve, and check valves.

Pressure control valves - types, direct operated types and pilot operated types.

Flow Control Valves - compensated and non-compensated FCV, needle valve, temperature compensated, pressure compensated, pressure and temperature compensated FCV, symbolic representation.

Hydraulic Circuit Design: Control of single and Double -acting hydraulic cylinder, regenerative circuit, pump unloading circuit, double pump hydraulic system, counter balance valve application, hydraulic cylinder sequencing circuits, cylinder synchronizing circuit using different methods, hydraulic circuit for force multiplication; speed control of hydraulic cylinder metering in, metering out and bleed off circuits. Pilot pressure operated circuits. Hydraulic circuit examples with accumulator.

COMPONENTS

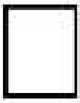
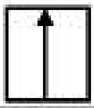
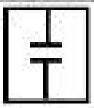
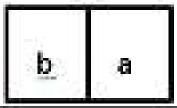
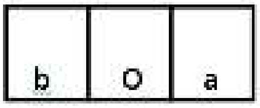
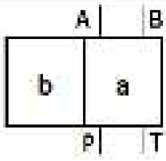
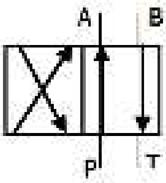
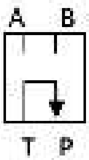
One of the most important consideration in any fluid power systems is the control. If the control components are not properly selected, the entire system will not function as required. Fluid power is controlled primarily through the use of control devices called valves. There are three types of valves:

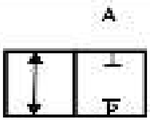
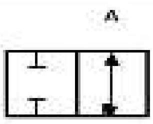
1. Direction control valves
2. Pressure control valves
3. Flow control valves

- The direction control valves determine the path through which fluid traverses in a given circuit.
- The pressure control valves protect the system against the excessive pressure, which may occur due to higher actuator loads or closing of valves.
- The flow control valves are used to control flow rate in various lines of a hydraulic circuit to control the actuator speeds.

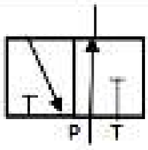
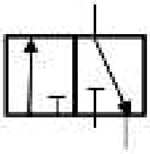
DIRECTION CONTROL VALVES:

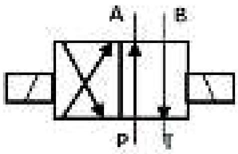
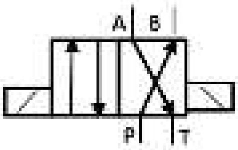
Symbolic Representation:

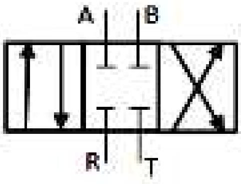
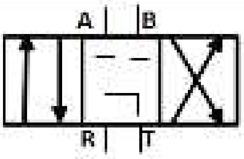
	Each individual switching portion is shown in a square
	Flow path is indicated by means of arrow within a square
	Closed position
	Two-position valve
	Three-position valve
	Ports added to the two-position valve
	Two flow paths
	Two ports are connected, two ports are closed

2/2-way valve: 2-ports and 2-position DCV	
	Normally closed position: P is not connected to A. When the valve is not actuated, the way is closed.
	Normally open position: P is connected to A. When the valve is not actuated, the way is open.

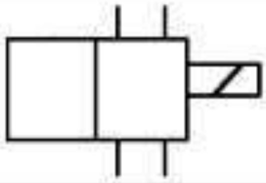
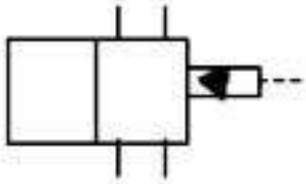
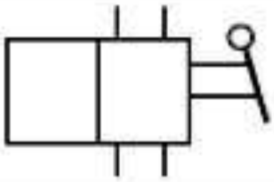
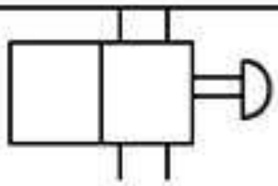
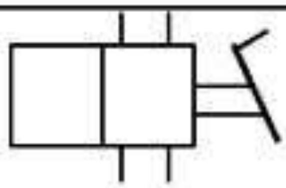
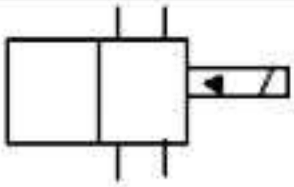
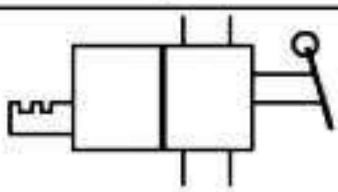
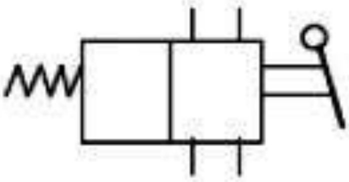
3/2-way valve: 3ports and 2 position DCV

	Normally open position: P is connected to A. When the valve is not actuated, the way is open.
	Normally open position: P is connected to A. When the valve is actuated, the way is closed

4/2-way valve – 4-port and 2-position DCV	
	P is connected to A B is connected to T
	Position 2: P is connected to B A is connected to T

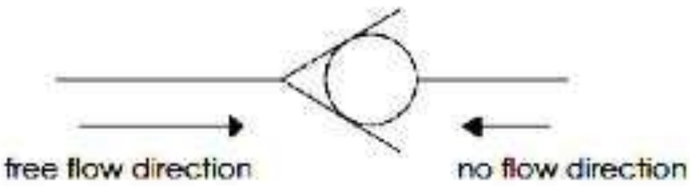
4/3-way valve – 4-port and 3-position DCV	
	P, T, A, B
	Mid-position pump reticulating: P to T, A and B closed

Actuating Devices:

	Solenoid operated
	Pilot operated
	Manual operated
	Push button
	Foot operated
	Pilot-operated solenoid
	Two-position detent
	Spring return

Check Valve:

The simplest DCV is a check valve. A check valve allows flow in one direction, but blocks the flow in the opposite direction. Figure shows the graphical symbol of a check valve along with its no-flow and free-flow directions.



Poppet Check Valve:

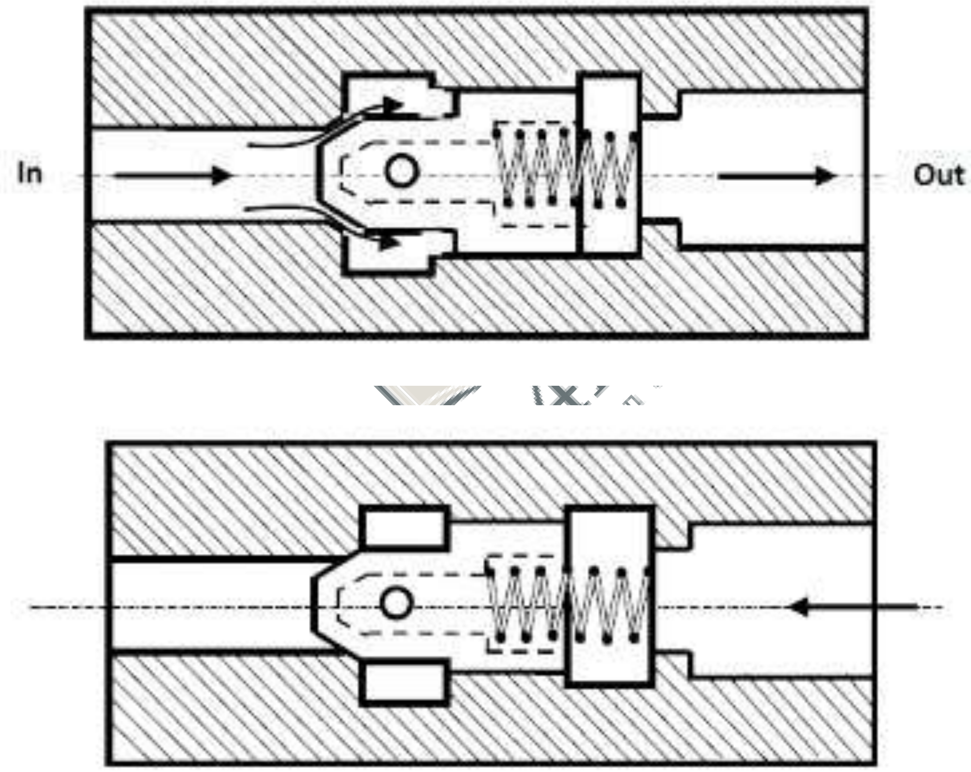
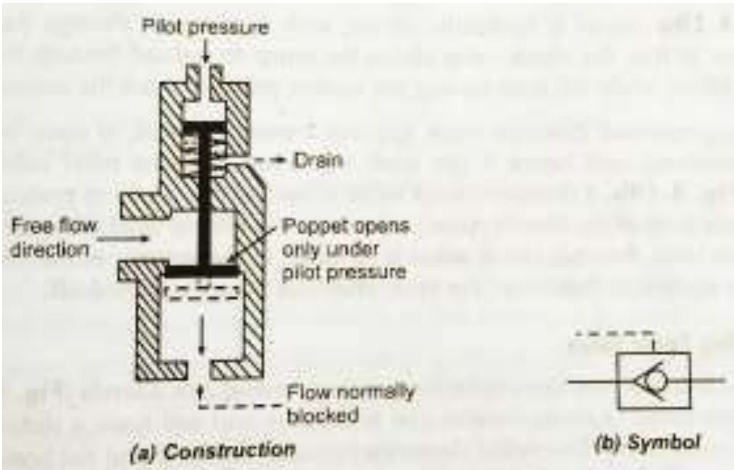


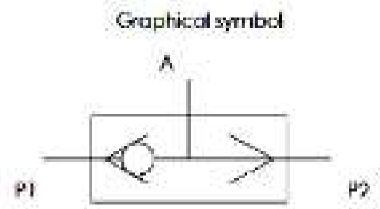
Figure shows the operation of a poppet check valve. A poppet is a specially shaped plug element held on a valve seat by a light spring. Fluid flows through the valve in the space between the seat and poppet. In the free flow direction, the fluid pressure overcomes the spring force. If the flow is attempted in the opposite direction, the fluid pressure pushes the poppet in the closed position. Therefore, no flow is permitted.

Pilot operated check valve (Pilot operated DCV):

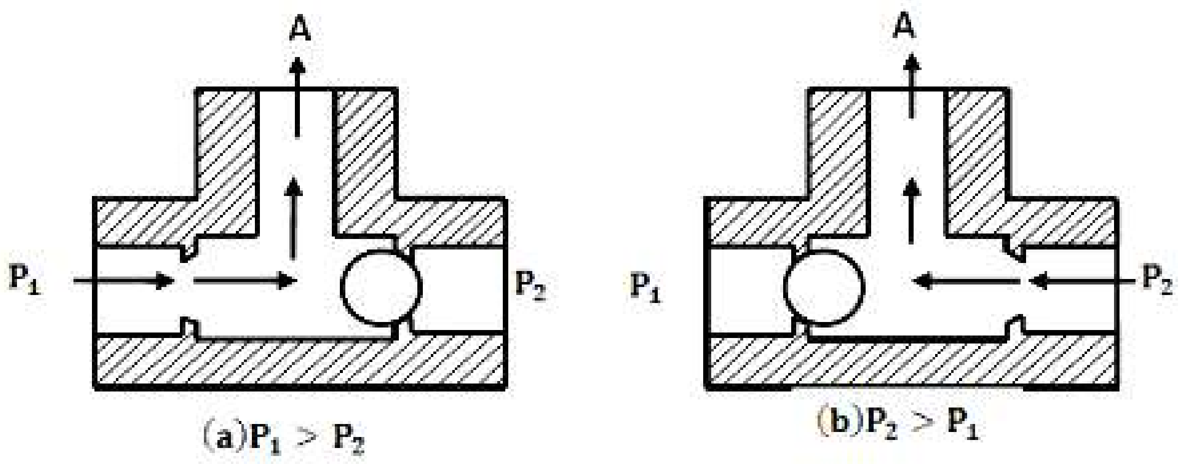
The pilot-operated check valve can permit flow in both the directions. In the normal operation, it functions like a check valve allowing free flow in one direction and blocking the flow in reverse direction. But when the pilot pressure is applied at the pilot port, it opens up the check valve and thus allows flow in the reverse direction. To achieve this function, the pilot piston is attached to the main poppet valve. The poppet is kept in normally closed condition with the help of a light spring.



Shuttle Valve:



A shuttle valve allows two alternate flow sources to be connected in a one-branch circuit. The valve has two inlets P1 and P2 and one outlet A. Outlet A receives flow from an inlet that is at a higher pressure. Figure shows the operation of a shuttle valve. If the pressure at P1 is greater than that at P2, the ball slides to the right and allows P1 to send flow to outlet A. If the pressure at P2 is greater than that at P1, the ball slides to the left and P2 supplies flow to outlet A.

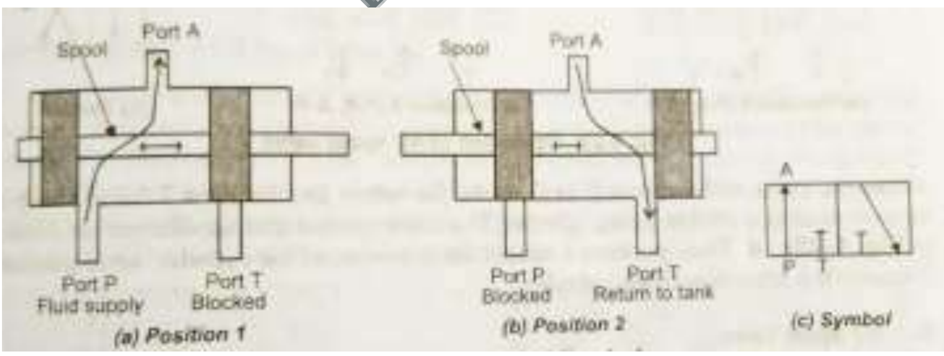


Sliding Spool Valve:

A spool is a step machined cylinder member, having 2 or 3 lands. The lands are machined to close dimensional tolerances and will have a sliding fit in the bore of the valve body. The openings formed between the lands on the spool act as the flow passages between the connecting ports.

3/2 Spool valve:

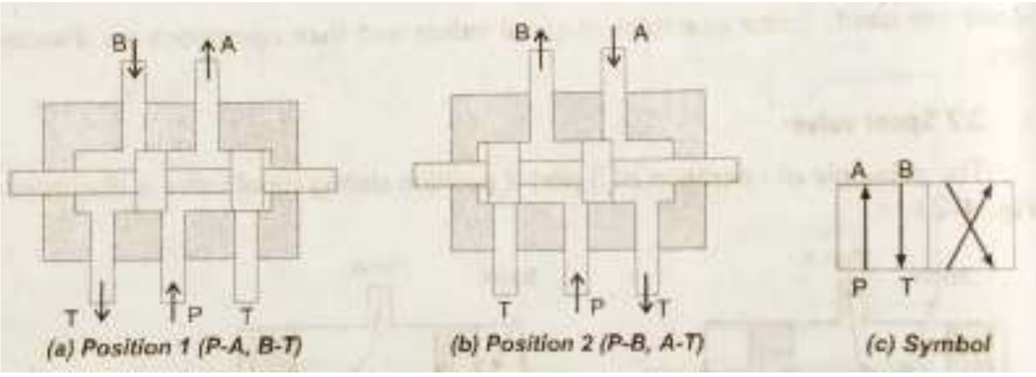
It has a cylindrical body with three ports P, T and A. Port P receives the fluid into the cylinder, Port A is connected to an actuation system and Port T is connected to the return line.



In operation, in the position 1, the fluid supply under pressure is connected to port P and port T is closed. That means pressure now flows through port A, and activates the device connected in that line. When the spool is moved to the position 2, the port P is closed, there by cutting the supply, while port is opened. Since there is pressure in the line (through port A), the pressure is relieved through the open port T and the fluid freely flows out the sump.

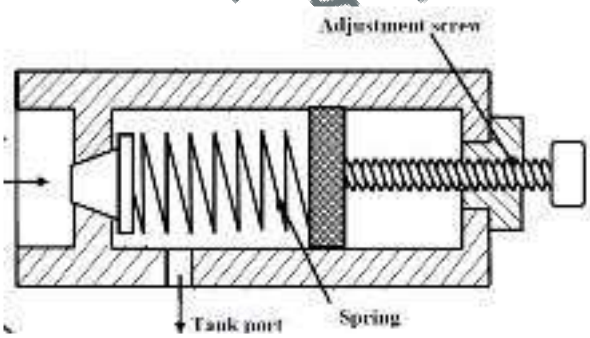
4/2 Spool Valve:

In position 1, the spool is connecting ports P to A, and ports B to T. This allows the pressure flow from P to A, while return from B to T. In position 2, the spool is connecting ports P to B and ports A to T. This allows the pressure flow from P to B, while return from A to T. Such a valve is used in double acting cylinder. Thus, position 1 causes the extension of the cylinder, while position 2 causes the retraction of the cylinder.



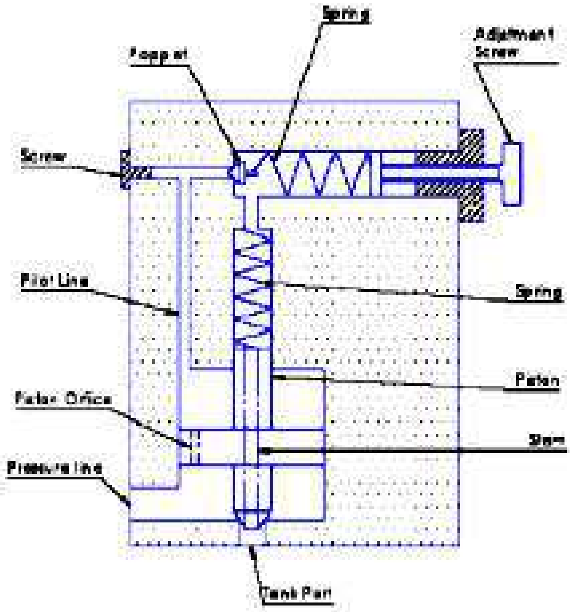
PRESSURE CONTROL VALVES:

Pressure Relief Valves:



The most widely used type of pressure control valve is the pressure-relief valve because it is found in practically every hydraulic system. It is normally a closed valve whose function is to limit the pressure to a specified maximum value by diverting pump flow back to the tank. A poppet is held seated inside the valve by a heavy spring. When the system pressure reaches a high enough value, the poppet is forced off its seat. This permits flow through the outlet to the tank as long as this high pressure level is maintained.

Compound Pressure Relief Valve (Pilot Operated Pressure Control Valve):

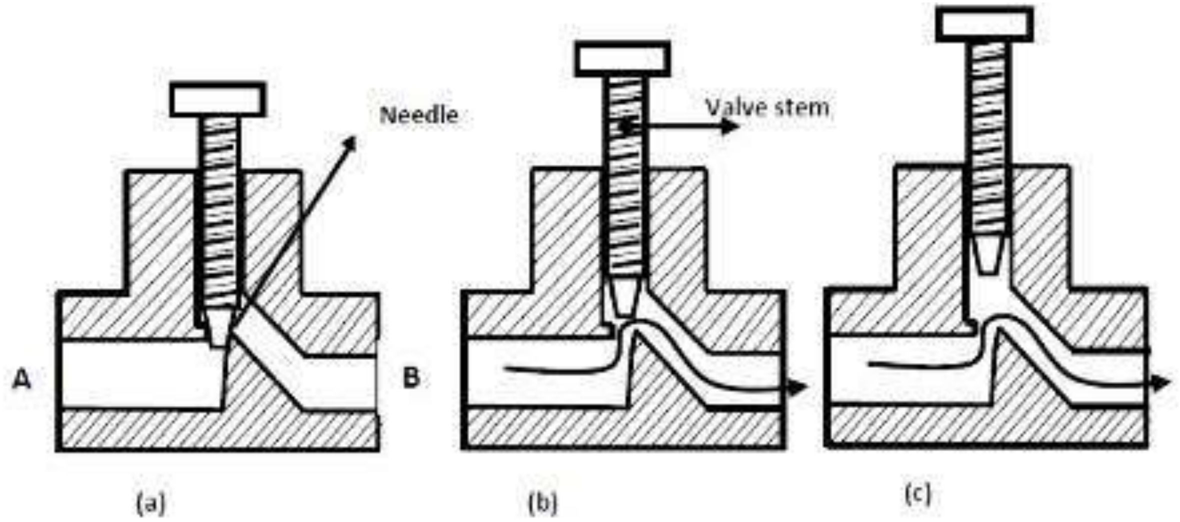


The pilot-operated pressure-relief valve has a pressure port that is connected to the pump line and the tank port is connected to the tank. The pilot relief valve is a poppet type. The main relief valve consists of a piston and a stem. The main relief piston has an orifice drilled through it. The piston has equal areas exposed to pressure on top and bottom and is in a balanced condition due to equal force acting on both the sides. It remains stationary in the closed position. The piston has a light bias spring to ensure that it stays closed. When the pressure is less than that of relief valve setting, the pump flow goes to the system. If the pressure in the system becomes high enough, it moves the pilot poppet off its seat. A small amount of flow begins to go through the pilot line back to the tank. Once flow begins through the piston orifice and pilot line, a pressure drop is induced across the piston due to the restriction of the piston orifice. This pressure drop then causes the piston and stem to lift off their seats and the flow goes directly from the pressure port to the tank.

Flow Control Valves:

Non-Pressure Compensated Flow Control Valves:

Non-pressure-compensated flow-control valves are used when the system pressure is relatively constant and motoring speeds are not too critical. The operating principle behind these valves is that the flow through an orifice remains 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.

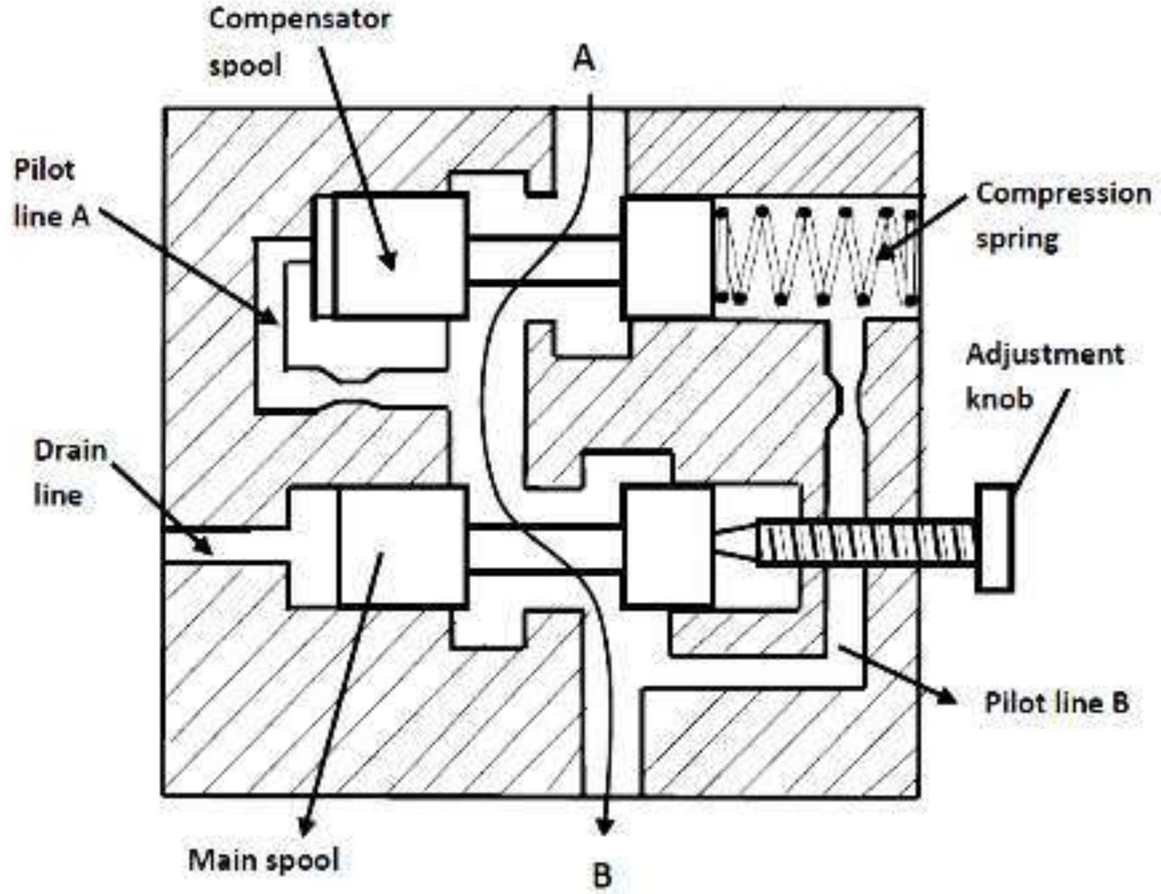


Non-pressure-compensated needle-type flow-control valve. (a) Fully closed: (b) partially opened: (c) fully opened.

It is the simplest type of flow-control valve. It consists of a screw (and needle) inside a tube-like structure. It has an adjustable orifice that can be used to reduce the flow in a circuit. The size of the orifice is adjusted by turning the adjustment screw that raises or lowers the needle. For a given opening position, a needle valve behaves as an orifice.

Pressure Compensated Flow Control Valve:

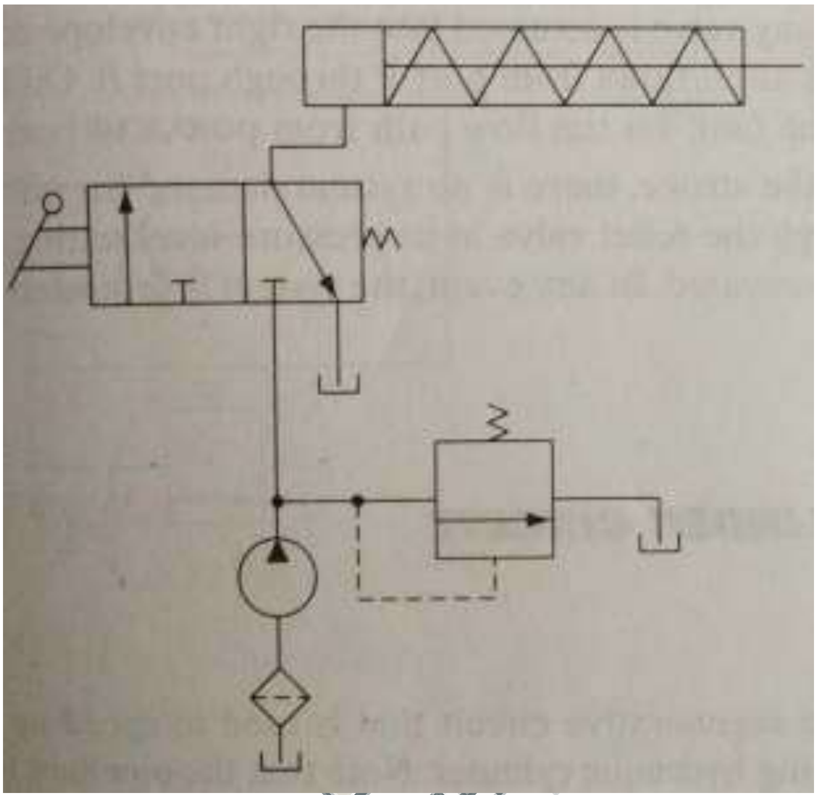
A pressure-compensated flow-control valve consists of a main spool and a compensator spool. The adjustment knob controls the main spool's position, which controls the orifice size at the outlet. The upstream pressure is delivered to the valve by the pilot line A. Similarly, the downstream pressure is ported to the right side of the compensator spool through the pilot line B. The compensator spring biases the spool so that it tends toward the fully open position. If the pressure drop across the valve increases, that is, the upstream pressure increases relative to the downstream pressure, the compensator spool moves to the right against the force of the spring. This reduces the flow that in turn reduces the pressure drop and tries to attain an equilibrium position as far as the flow is concerned.



In the static condition, the hydraulic forces hold the compensator spool in balance, but the bias spring forces it to the far right, thus holding the compensator orifice fully open. In the flow condition, any pressure drop less than the bias spring force does not affect the fully open compensator orifice, but any pressure drop greater than the bias spring force reduces the compensator orifice. Any change in pressure on either side of the control orifice, without a corresponding pressure change on the opposite side of the control orifice, moves the compensator spool. Thus, a fixed differential across the control orifice is maintained at all times. It blocks all flow in excess of the throttle setting. As a result, flow exceeding the pre-set amount can be used by other parts of the circuit or return to the tank via a pressure-relief valve.

HYDRAULIC CIRCUITS:

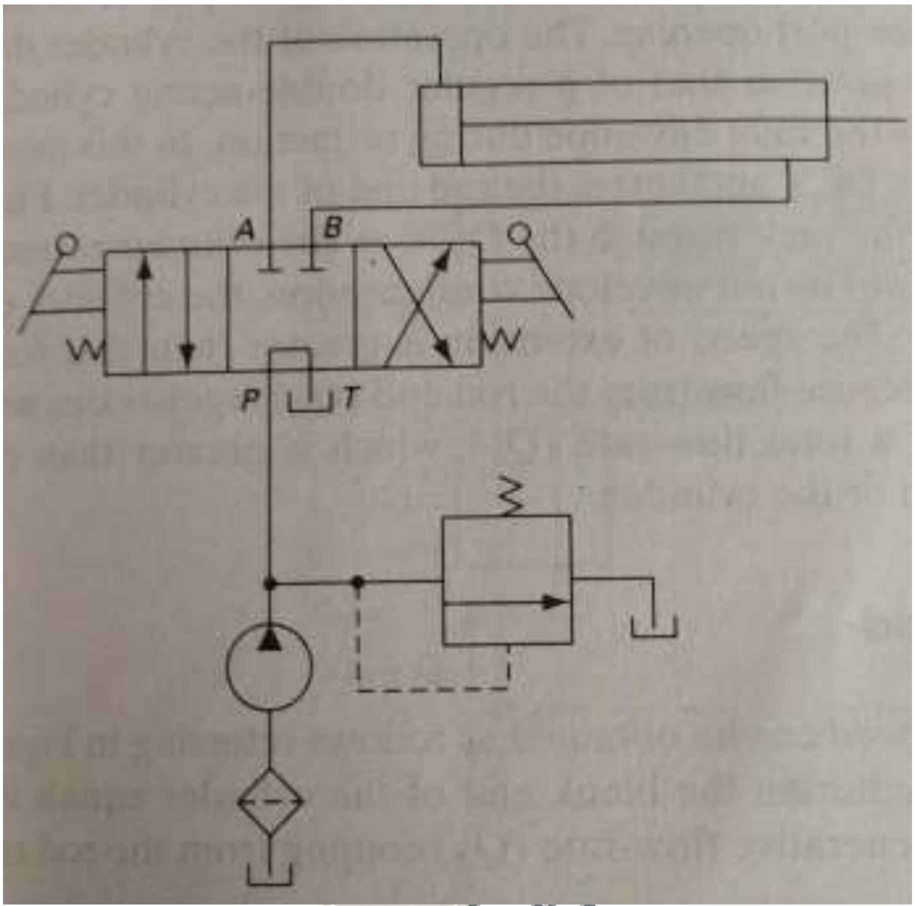
Control of a Single-Acting Hydraulic Cylinder:



The circuit has a filter, pump, pressure relief valve, a DCV and a spring return single acting cylinder. In operation, with the cylinder in normally retracted position (under spring pressure), when the valve is operated manually, the pressure port opens, the pump flow is directed to the piston end of the cylinder and causes extension of cylinder. Once, the extension is achieved, PRV opens-out and flow starts to pass through the PRV in the bypass line. When the DCV is deactuated, the pressure port is blocked, and the oil from the piston end of cylinder is routed to tank line. The cylinder starts retracting under spring pressure, and the oil flows back to the tank.

Control of a Double-Acting Hydraulic Cylinder:

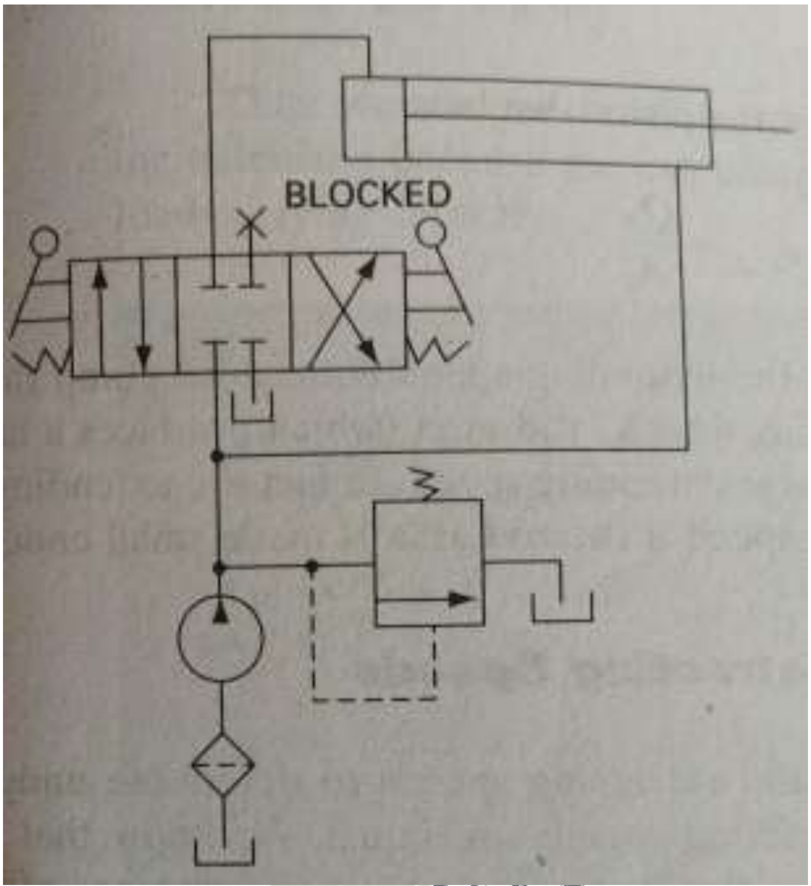
Four-way DCVs are commonly used to control the operation of double acting cylinders. Here the valve shown in three positions: under extension (left envelope), neutral position (central envelope) and under retraction (right envelope).



With the envelope in neutral position, the pump flow will continuously flow back to the tank through the DCV. Hence with this, the actuator and the pump are not pressurised. When the valve is actuated to the left envelope position, the pressure line is connected to the piston end cylinder port, while rod-end cylinder port is directed to the tank line. Under the pump pressure the cylinder extends and at the same time, the oil from the rod end freely flows back to the tank through the DCV. At the end of the stroke until the DCV is deactivated, the flow goes through the PRV. When the valve is actuated to the right envelope position, the pressure line is connected to the rod-end port, and the piston-end port is connected to the tank line. This causes cylinder retraction, with the oil from piston-end flowing freely back into the tank. At the end of the stroke, the pressure builds up, the PRV opens out and the fluid flows through the relief line.

Regenerative Cylinder Circuit:

Figure shows a regenerative circuit that is used to speed up the extending speed of a double-acting hydraulic cylinder.

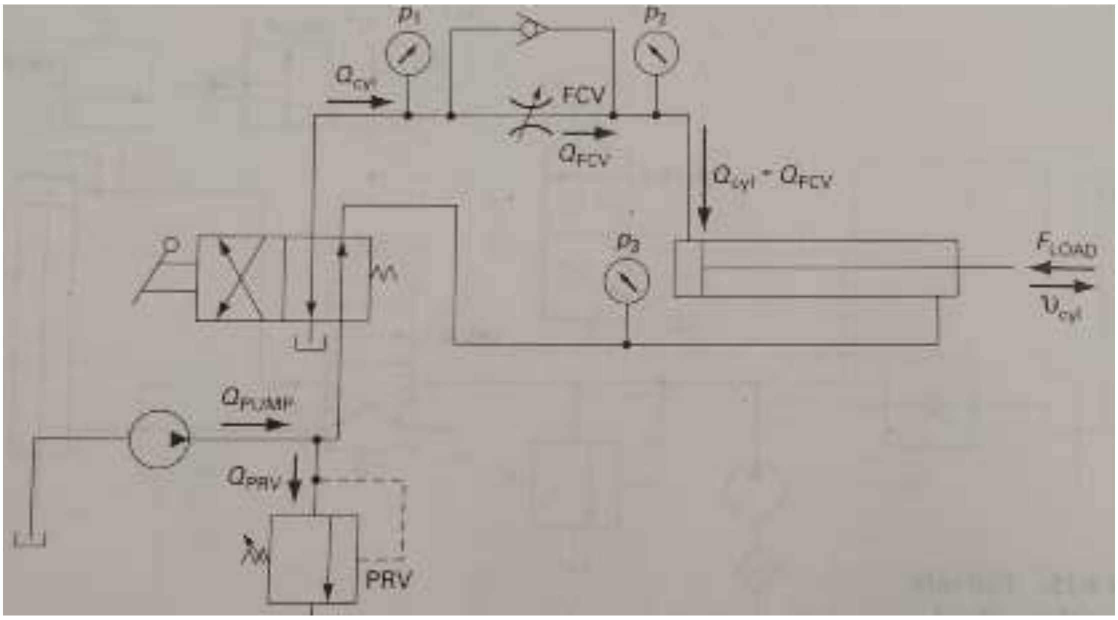


Note that the pipelines to both ends of the hydraulic cylinder are connected in parallel and that one of the ports of the four-way valve is blocked. Fluid flows through the DCV via the right envelope during retraction. In this mode, fluid from the pump bypasses the DCV and enters the rod end of the cylinder. Fluid in the blank end drains back to the tank through the DCV as the cylinder retracts.

When the DCV is shifted into its left envelope configuration, the cylinder extends. The speed of extension is greater than the that for a regular double-acting cylinder because flow from the rod end regenerates with pump flow to provide a total flow rate, which is greater than the pump flow rate to the blank end of the cylinder.

Meter-in Circuit:

Cylinder speeds can be controlled with the use of Flow Control Valves (FCV). The use of FCV to control the inlet flow to the cylinder hence the speed control is termed meter-in control.



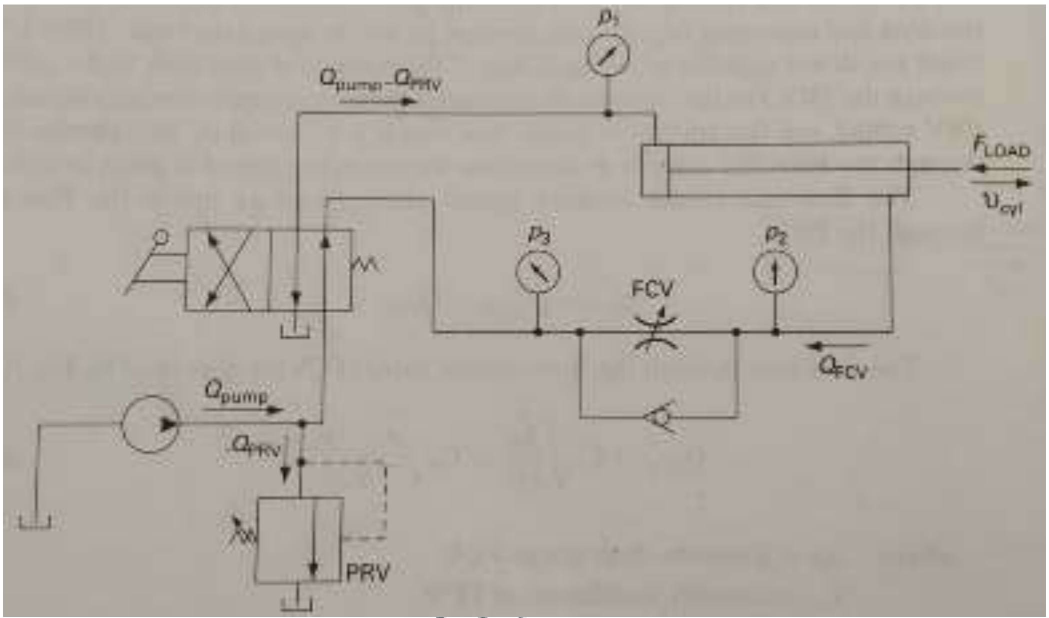
The operation of the cylinder to control its extension speed is explained with respect to two valve positions. When the DCV is actuated manually to its right envelope mode, the flow from the pressure line is directed to the piston-end port of the cylinder through the FCV. Note that though there is a check valve, it is in closed position and the flow is forced to pass through the metering orifice. Thus depending upon the orifice opening the flow is metered to the inlet port. Hence the extending speed of the cylinder is controlled.

When the DCV is actuated manually to its left envelope mode, the flow lines are reversed. The pressure line is directed to the rod-end port in the cylinder while piston-end port is connected to the tank line. The cylinder starts retracting as the flow enters the rod-end port, and at the same time the flow from the piston-end passes through the FCV. Note that the check valve opens-out, thus the flow bypasses the orifice valve and passes through the least resistance path, that is through the check valve without any restriction. Thus in retraction, the cylinder moves back at its full design speed.

Meter-out Circuit:

The use of FCV to control the outlet flow from the cylinder hence its speed is termed as meter-out circuit. The operation of the cylinder to control its extension speed is explained with respect to two valve positions.

When the DCV is actuated manually to its right envelope mode, the flow from the pressure line is directed directly to piston-end port of the cylinder. As the cylinder extends, the fluid from the rod-end of the cylinder is forced out of the port. Since there is a FCV, the flow has to pass through it. As there is a restriction to the flow through the FCV, the flow rate is metered. Though the piston is pushing the fluid out with full force, it is resisted by the FCV hence the extension speed is controlled. Note that though there is a check valve along with the FCV, it is a one-way valve and remains closed when the fluid is being forced out of rod-end port to the tank line.

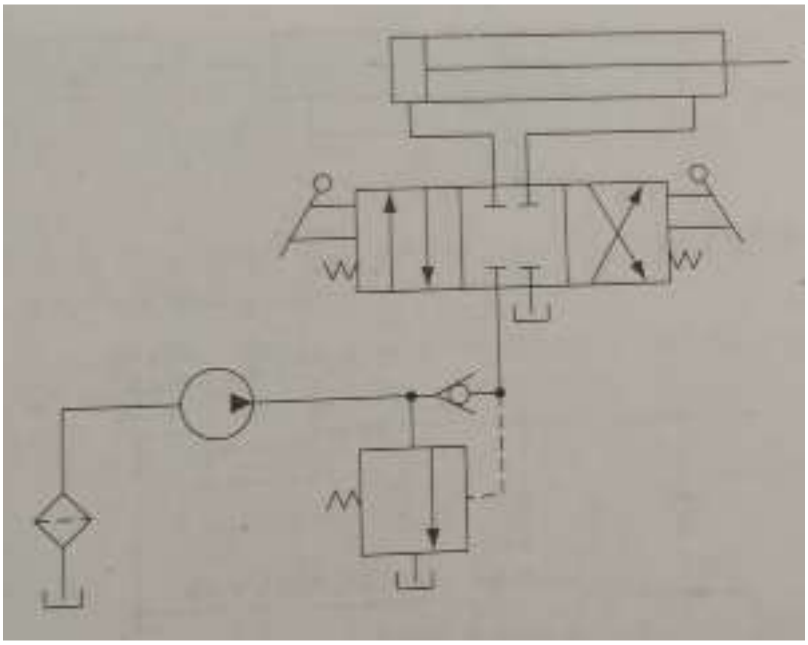


When the DCV is actuated to the left envelope mode, the flow lines are reversed. The pressure line is directed to rod-end port of the cylinder, while the piston-end port is connected to the tank line. The fluid under pressure enters rod-end port through the FCV, but bypassing the orifice. Instead it flows through the check valve, which now opens out due to favourable direction of flow. There is no restriction of flow through the check valve in this direction, hence full flow enters the cylinder, and it retracts with full design speed.

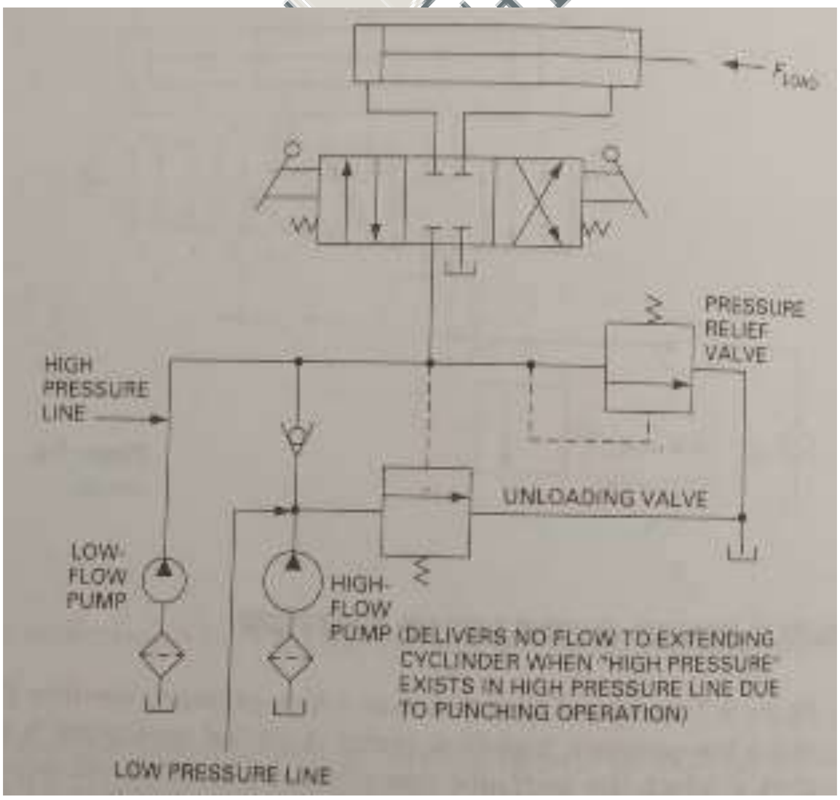
Pump Unloading Circuit:

An unloading valve is used to unload a pump in the circuit. The unloading valve opens when the cylinder reaches the end of its extension stroke because the check valve keeps high pressure oil in the pilot line of the unloading valve. When the DCV is shifted to retract the cylinder, the motion of the piston reduces the pressure in the pilot line of the unloading valve.

This resets the unloading valve until the cylinder is fully retracted, at which point the unloading valve unloads the pump.



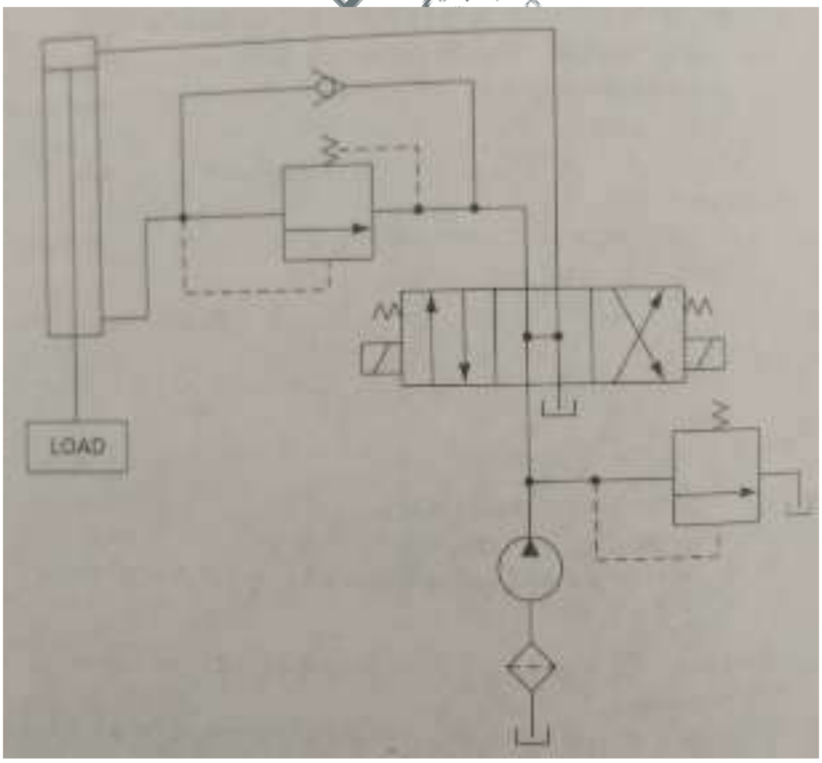
Double-Pump Hydraulic Circuit:



It uses a high pressure, low flow pump in conjunction with a low pressure, high flow pump. A typical application is a sheet metal punch press in which the hydraulic ram must extend rapidly over a great distance with very low pressure but high flowrate requirements. This rapid extension of the cylinder occurs under no load as the punching tool (connected to the end of the cylinder piston rod) approaches the sheet metal strip to be punched. However, during the short motion portion when the punching operation occurs, the pressure requirements are high due to the punching load. During the punching operation, the cylinder travel is small and thus the flowrate requirements are low.

The circuit eliminates the necessity of having a very expensive high pressure high flow pump. When the punching operation begins, the increased pressure opens the unloading valve to unload the low pressure pump. The purpose of the relief valve is to protect the high pressure pump from overpressure at the end of the cylinder stroke and when the DCV is in spring centred mode. The check valve protects the low pressure pump from hig pressure, which occurs during the punching operation, at the end of cylinder stroke, and when the DCV is in its spring centred mode.

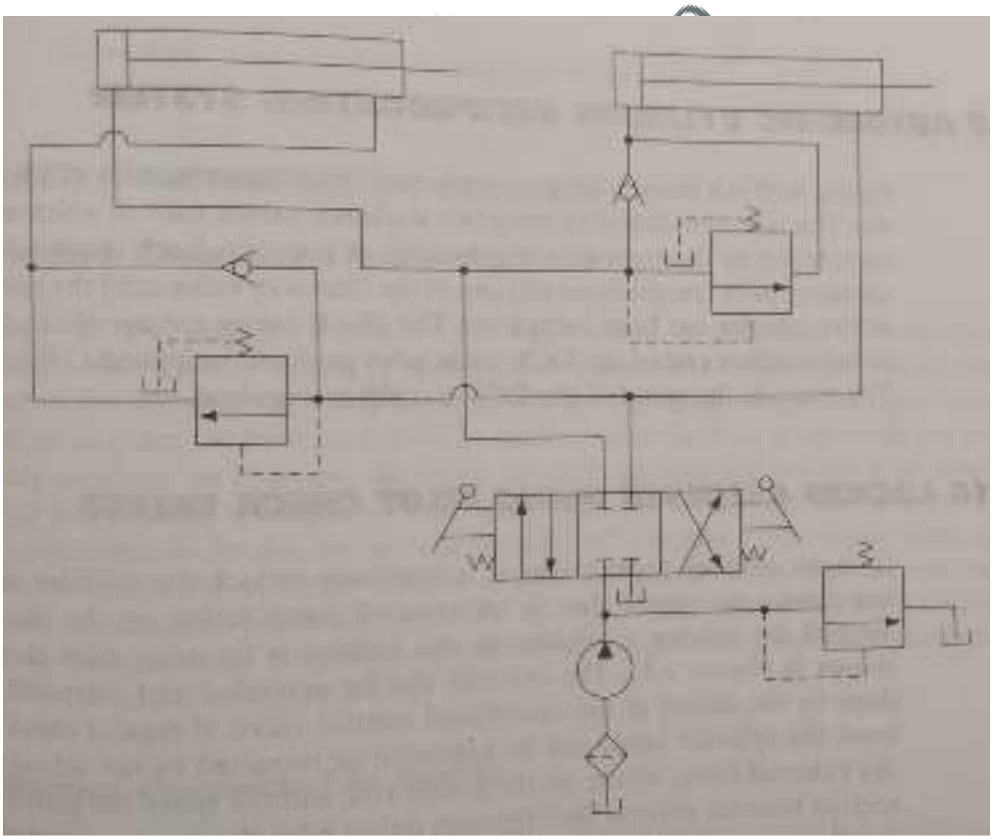
Counterbalance Valve Application Circuit:



Here a counterbalance or backpressure valve is used to keep a vertically mounted hydraulic cylinder in the upward position while the pump is idling. The counterbalance valve is set to open at somewhat above the pressure required to prevent the vertical cylinder from descending due to the weight of its load. This permits the cylinder to be forced downward when pressure is applied on the top. The open centre directional control valve unloads the pump.

Hydraulic Cylinder Sequencing Circuits:

A sequence valve causes operations in a hydraulic circuit to behave sequentially. When the DCV is shifted into its left envelope mode, the left cylinder extends completely, and then the right cylinder extends. If the DCV is then shifted into its right envelope mode, the right cylinder retracts fully, and then the left cylinder retracts. This sequence of cylinder operation is controlled by the sequence valves. The spring centered position of the DCV locks both cylinders in place.



QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS:

DEC 2015/JAN 2016

1) Write the symbols representing various centre flow paths for two position four way valves.
2) Explain the operational features of the compound pressure relief valve.
3) Explain the construction and operation of a simple needle valve and also explain the expression for the flow rate through flow control valve.
4) Explain the concept of Meter in and Meter out circuit. List the advantages and limitations of each of the circuit
5) Explain regenerative circuit with a neat diagram and deuce regenerative speed of the cylinder.

JUNE/JULY 2016

1) Briefly classify valves based on the type of function performed.
2) Sketch and explain the constructional features of poppet valve.
3) Sketch and explain pressure compensated flow control valve.
4) Sketch and explain the operation of a hydraulic circuit for the control of a spring return single acting cylinder.
5) What is regenerative circuit? Sketch schematically regenerative circuit to increase the extension speed of a double acting cylinder.

DEC 2016/JAN 2017

1) Explain the working principle of pilot operated check valve with a neat sketch. Illustrate the graphical symbol of the valve.
2) Explain with the aid of sketches:
   i) Non-compensated flow control valve
   ii) Compensated flow control valve
3) Explain the concept of Meter In and Meter Out circuit.
4) With a neat sketch, explain hydraulic circuit for sequencing of two cylinders.

JUNE/JULY 2017

1) Explain pressure reducing valve with graphical symbol.

2) Explain with a sketch non-compensated flow control needle valve.
3) With circuit diagram explain meter in circuit for controlling the speed of hydraulic cylinders.
4) Describe with a circuit diagram the construction and working of a counterbalance valve in hydraulic circuit.

DEC 2017/JAN 2018

1) Explain with neat sketch of 3/2 poppet valve with symbolic representation.
2) Explain with neat sketch of pilot operated pressure relief valve.
3) Explain with a neat sketch the working of shuttle valve with symbolic representation.
4) Explain with a neat circuit diagram, the working of double pump hydraulic system.
5) Explain with a neat circuit diagram, the counter balance valve application.

JUNE/JULY 2018

1) How control valves are classified?
2) Explain with a neat sketch the working of a Direct Acting Pressure Relief valve.
3) Describe the working of 5/3 DC valve with 4 ways with neat sketches. Also draw its graphical symbol.
4) What is the principle and purpose of regenerative circuit? Explain the working of a typical regenerative circuit with neat sketch.

CRASH COURSE – MAY 2017

1) With the aid of an appropriate hydraulic circuit explain the principle of unloading valve.
2) With the aid of neat sketch explain briefly the following:

i) Pressure reducing valve

ii) Pressure compensated flow controlled valve.

Give the graphic symbol for each.

3) Describe with the aid of an appropriate hydraulic circuit hydraulic cylinder sequencing.

ONE TIME EXIT SCHEME – APRIL 2018

1) Give the classification of hydraulic control valve. With a neat sketch, explain simple pressure relief valve and give its graphical symbol.
2) Explain compensated and non-compensated flow control valve. Also draw the symbol.

3) With a neat sketch, explain pump unloading circuit.
4) With neat sketch, explain hydraulic cylinder sequencing circuit used in hydraulic drill press.

MODULE 4: PNEUMATIC POWER SYSTEMS

Introduction to Pneumatic Systems: Pneumatic power system, advantages, limitations, applications, choice of working medium. Characteristics of compressed air and air compressors. Structure of pneumatic control system, fluid conditioners – dryers and FRL unit.

Pneumatic Actuators: Linear cylinder – types of cylinders, working, end position cushioning, seals, mounting arrangements and applications. Rotary cylinders – types, construction and application, symbols.

Pneumatic Control Valves: DCV such as poppet, spool, suspended seat type slide valve, pressure control valves, flow control valves, types and construction, use of memory valve, Quick exhaust valve, time delay valve, shuttle valve, twin pressure valve, symbols.

INTRODUCTION

The working concept of a pneumatic system is similar to that of a hydraulic power system. Pneumatic systems use pressurised gas, mostly air, to transmit motion and power.

CHOICE OF WORKING MEDIUM:

The choice of the working medium depends basically on the type of application. Some of the general, broad rules followed in the selection of a working medium are listed below:

i) When a system needs high speed, medium pressure and less accuracy a pneumatic system is good. If the system requires high pressure and high accuracy, a fluid system with oil is good.

ii) When the power requirements are very high, like in a power press, oil hydraulics is the option.

iii) Location of the system also plays a role in the selection of a working medium. For location with severe temperature variations, oil hydraulic system will do better, where an air system may lead to severe condensation problems.

iv) Another issue related to the selection of working medium is that of fire/electric hazards. Air being non-explosion in nature, it is preferred where fire/electric hazards are expected. Oil systems are more prone to fire and electrical hazards and are not recommended in such areas.

CHARACTERISTICS/ADVANTAGES OF COMPRESSED AIR (PNEUMATIC SYSTEMS):

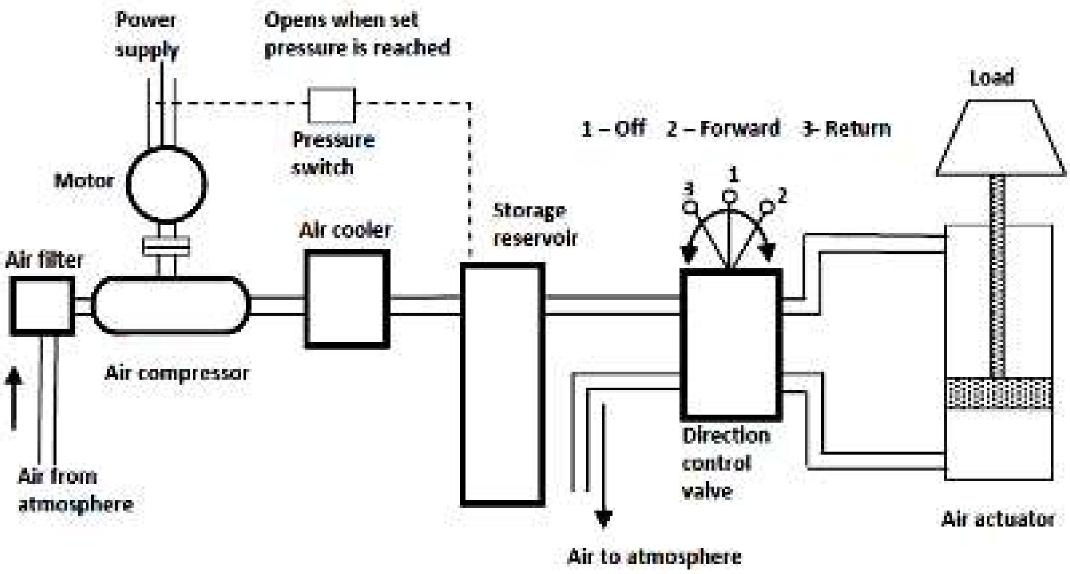
i) Air is available in abundance at all locations.
ii) Air can be transported from the source to the point of utilisation very conveniently through piping layout, and there are no limitations on the distance.
iii) Compressed air can be stored conveniently in a reservoir and used whenever required.
iv) Compressed air is free from explosion and electrical hazard problems.
v) Air is clean and has no leakage/messy problems like hydraulic fluids.
vi) Generally, temperature variations do not affect the performance of air systems, as long as good air treatment systems (filter, regulator, lubricator) are maintained.
vii) Most components of air system are simple and compact in design.

DISADVANTAGES OF COMPRESSED AIR (PNEUMATIC SYSTEMS):

i) **Power:** Air as a working medium is not useful for high power and high precision applications, since it is compressible in nature.
ii) **Lubrication:** Air is not a good lubricating medium unlike the hydraulic fluid.
iii) **Heat Dissipation:** Air due to its low conductivity, cannot dissipate heat as much as a hydraulic fluid.
iv) **Sealing:** Air cannot seal the fine gaps between the moving parts unlike the hydraulic fluid.
v) **Noise & Condensation:** Air as a working medium is always noisy, and is prone to severe condensation problems with temperature variations.

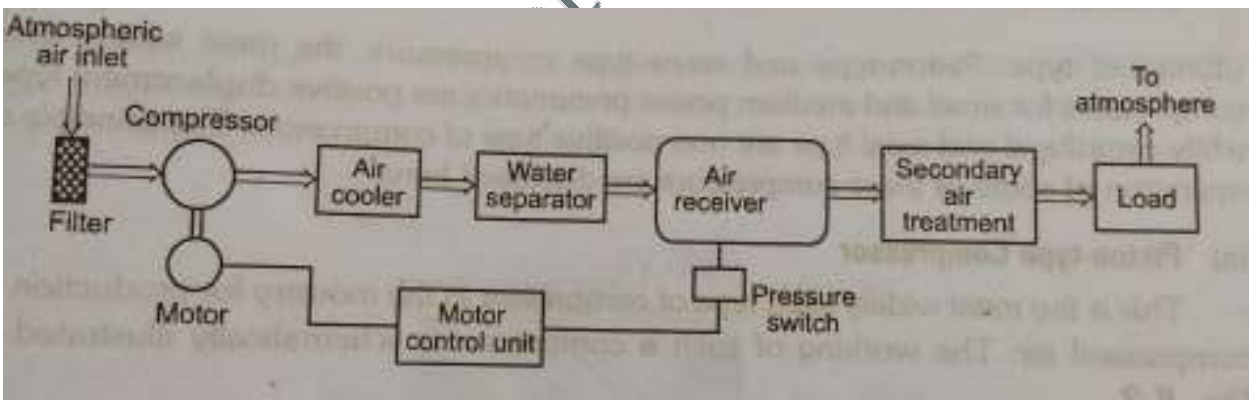
STRUCTURE OF A PNEUMATIC SYSTEM:

In this system, an electric motor drives an air compressor. The atmospheric air is sucked by the compressor through the filter. The purpose of the filter is to separate air from suspended and other dust particles. The compressor line is provided with a pressure switch, to protect the system pressure rising beyond the safe level by stopping the electric motor supply. Since the compression process increases the temperature of the compressed air, the air is passed through an air cooler to cool the air to environmental condition. This air is then stored in a storage reservoir, usually a large cylindrical steel container. From the reservoir, the compressed air is supplied to various systems for use.



PRODUCTION OF COMPRESSED AIR:

Compressed air is produced using compressors and stored in a reservoir. Before the atmospheric air is drawn into the compressor, it passes through a filter to remove the atmospheric dirt and other particles so that only clean air enters the compressor. In the compressor unit run by an electric motor, the volume of the drawn air is reduced so that its pressure increases. This increase in pressure is associated with an increase in temperature of the compressed air. Hence an air cooler is use to cool the air before it is sent to reservoir.



Since the atmospheric air is humid, after compression and cooling, it condenses into small droplets. This moisture causes corrosion and operational problems. A separator is used to remove water particles from the compressed air. This air after cooling and separation (i.e., primary treatment) is sent to the reservoir. Once the reservoir is filled with compressed air and pressure reaches a safe limit value, it is sensed by a pressure switch, which in turn switches the compressor-motor off. With usage the pressure drops down, which is again sensed by the pressure switch, and in turn switches the motor on.

In pneumatic systems, unlike the hydraulic systems, the compressed air has no lubricating ability. Thus, the stored air before being sent to do some work is mixed with an oil mist. This not only provides lubrication to mating parts, but also reduces the corrosive problems. In practice, the compressed air after mixing with oil mist is further subjected to filtering and moisture separation again to make the air further clean. This treated air is then sent to the control valves and to the actuators to do the work.

PERFECT GAS LAWS:

The laws that determine the interactions of pressure, volume and temperature of a gas are called the "perfect gas laws". Even though perfect gases do not exist, air behaves very closely to that predicted by Boyle's law, Charle's law, Gay-Lussac's law and general gas law for the pressure and temperature ranges experienced by pneumatic systems.

Boyle's Law:

It states that if the temperature of a given amount of gas is held constant, the volume of the gas will change inversely with the absolute pressure of the gas.

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

Charles' Law:

It states that if the pressure on a given amount of gas is held constant, the volume of the gas will change in direct proportion to the absolute temperature.

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Gay-Lussac's Law:

It states that if the volume of a given gas is held constant, the pressure exerted by the gas is directly proportional to its absolute temperature.

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

General Gas Law:

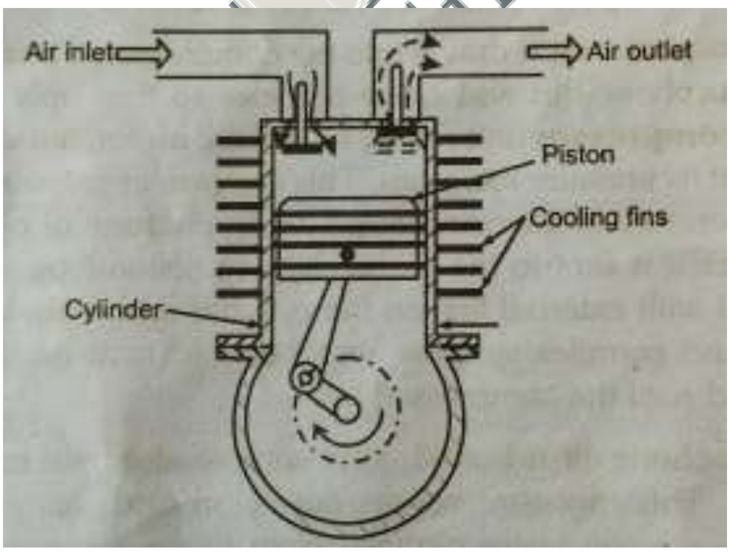
It contains all three gas parameters (pressure, temperature and volume), since none are held constant during a process from state 1 to state 2. It is defined as

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

COMPRESSORS:

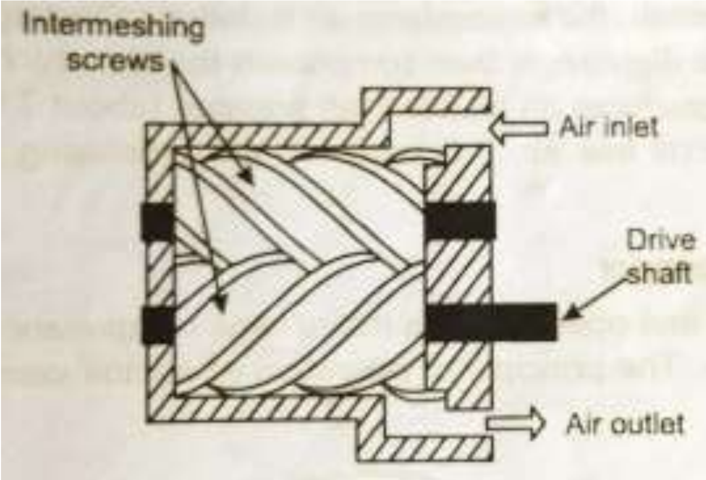
Compressors are the source of pneumatic power. These can be classified into two categories: positive displacement and non-positive displacement type. Piston-type and screw-type are positive displacement type and most widely used compressors for small and medium power pneumatic applications, while centrifugal and axial type are non-positive type.

Piston-type Compressor:



This is the most widely used type of compressor in the industry for production of compressed air. It has a piston-cylinder arrangement, with inlet and outlet valves. The piston is driven by a crank and connecting rod, which converts the rotary motion of the motor into reciprocating motion of the piston. In operation, in the first cycle (the half revolution of the shaft) the inlet valve opens, the atmospheric air is drawn-in by the piston as it moves down. In the next cycle (the second half revolution of the crank shaft), the inlet valve gets closed, the outlet valve opens and the air is compressed as the piston moves up in the cylinder. The air compression process is accompanied with an increase in temperature. The air is cooled by providing fins around the cylinder.

Screw-type Compressor:



A screw compressor is a rotary type compressor, which is simple in construction and operation. It has two intermeshing rotating screws with close working tolerances. These screws are housed in a casing with inlet and outlet ports. In operation as the screw rotate, the atmospheric air is drawn-in, trapped between the rotating/meshing screws, which is carried along the screws up to the outlet port. Since, the screws mesh continuously, the air compression and delivery occurs continuously without any pulsation. For wear free and reduced noise operation some kind of lubrication forming a thin oil film is used. The oil injected to the chamber lubricates the screw surfaces and forms a seal so that air is compressed efficiently, as the screws mesh continuously.

FLUID CONDITIONERS:

The compressed air gets contaminated due to atmospheric dust, lubricant, moisture and so on. If this air is used directly it may block the control valves, damage the components and/or cause corrosion related problems. Hence, before it is actually used for pneumatic application the air is prepared by removing various contaminants. Fluid conditioners include filters, regulators, lubricators and air dryers.

Air Filters:

Filters are provided both at the compressor inlets and in the pneumatic lines before the valves/actuators. Intake filters are mostly paper type elements, which prevent the entry of atmospheric contaminants into the compressor and minimise damage to the compressor components. The other filter, termed the air-line filter is used in the pneumatic lines to remove contaminants, mainly fine dirt and moisture. The air-line filters protect the pneumatic control valves and other devices.

Air Dryer:

The air filter can only remove condensed water particles from air. The vapour passes through the air-filter and causes problems as it condenses at other components. In a compressed air, the relative humidity (RH) and dew point are higher. Both the RH and the dew point are dependent on the temperature and pressure. Whenever the temperature drops and/or the pressure increases the water condenses. This problem can be reduced by keeping the humidity of air below 100%, for which air-dryers are used.

Lubricators:

Unlike the hydraulic systems, the dry air in the pneumatic systems cannot provide a lubrication effect in the devices. Generally, oil in the form of fine mist is added to the clean dry air during the secondary treatment. For this air lubricators are used.

Air Pressure Regulator:

In pneumatic systems the flow velocities are quite high, which may lead to considerable pressure drops between the air receiver and the loading point. Hence, it is a common practice to maintain a higher pressure in the reservoir than that is required at the actuator. The required pressure at the loading point is then achieved using pressure regulation locally using air pressure regulators.

Air pressure regulators are similar to pressure reducing valves used in hydraulic systems. Air pressure regulators in pneumatic systems are used to adjust the supply pressure to a required level for a given load irrespective of the air flow, i.e., to maintain a constant pressure at the load: that means, if the air flow is higher, it senses the pressure and reduces the flow rate to the required level to maintain the pressure. Similarly, if the supply pressure drops, the regulator increases the flow rate so as to increase the pressure to the required level.

PNEUMATIC ACTUATORS

Pneumatic actuators convert the air pressure into linear or rotary motion depending upon their design. Similar to hydraulic actuators, pneumatic cylinders are also use for gripping/moving of objects in various industrial applications. Pneumatic actuators which are designed to produce linear motion are termed linear air cylinders. Actuators which are designed to produce rotary motion are termed rotary cylinders or more popularly air motors.

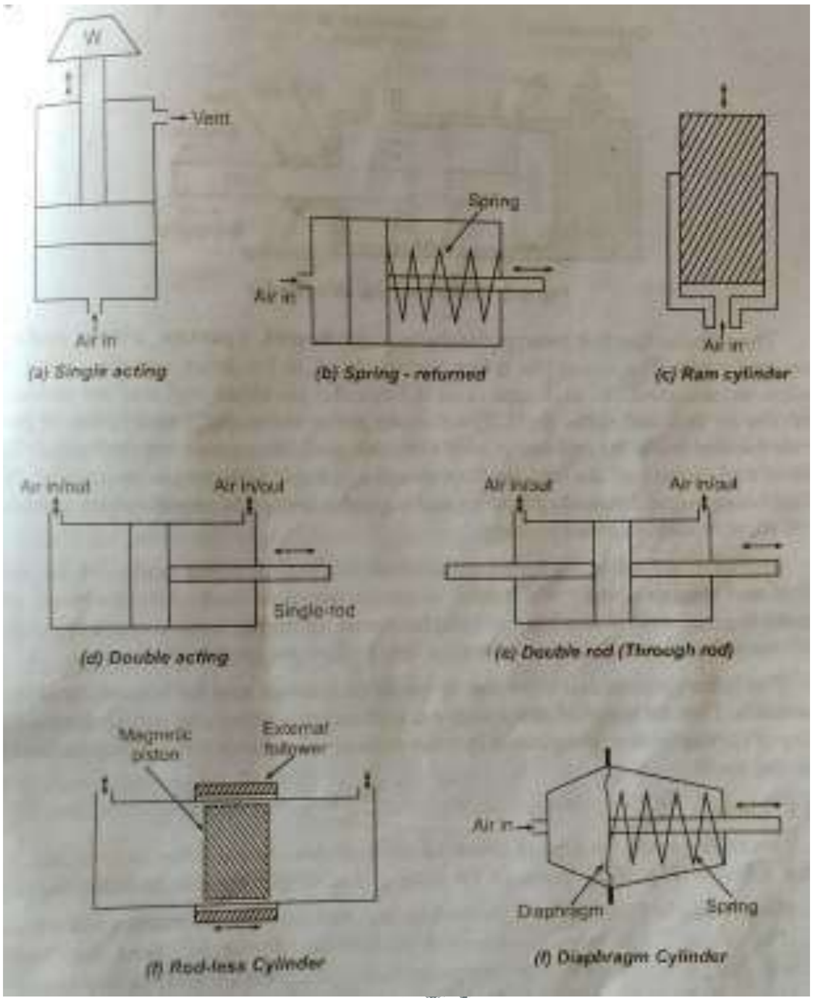
Linear Cylinders:

Classification of Air Cylinders:

Linear pneumatic cylinders, popularly known as air cylinders are used for the generation of straight rectilinear motion. Thus, they are useful to move an object or apply a force on an object in a straight line.

Pneumatic cylinders are briefly classified as follows:

1) **Single acting cylinder:** It is a cylinder in which air pressure is applied on to the piston side only and extension takes place by the air pressure in one direction. The return stroke is mostly by gravity.
2) **Spring Return Cylinder**: It is a single acting cylinder in which movement in one direction is under air pressure, while the return stroke is accomplished by a spring.
3) **Ram Cylinder:** in this the cylinder rod itself forms the movable element termed as ram. It is usually single acting and return stroke is either under gravity or assisted by return cylinders.



4) **Double acting cylinder:** it is a cylinder in which the ait pressure is applied alternately on either side, so that
5) **Double rod or through-rod cylinder:** In a double-rod or through-rod cylinder, the piston-rod extends/retracts on either end of the cylinder.
6) **Rod-less cylinder:** In this, there is no rod connected to the piston. Usually, the piston is a magnetic type, while an external follower (magnetic) follows the piston due to magnetic coupling.
7) **Diaphragm Cylinder:** For short stroke lengths, small cylinders with a rubber or metal diaphragm is used instead of a piston. The main advantage of such cylinders is that there is no leakage between the inlet and outlet chambers; and there is no frictional loss.

SEALS:

Seals are used to avoid leakage and for smooth, wear free operation. Depending upon the type of construction, seals are used at different locations in a linear cylinder.

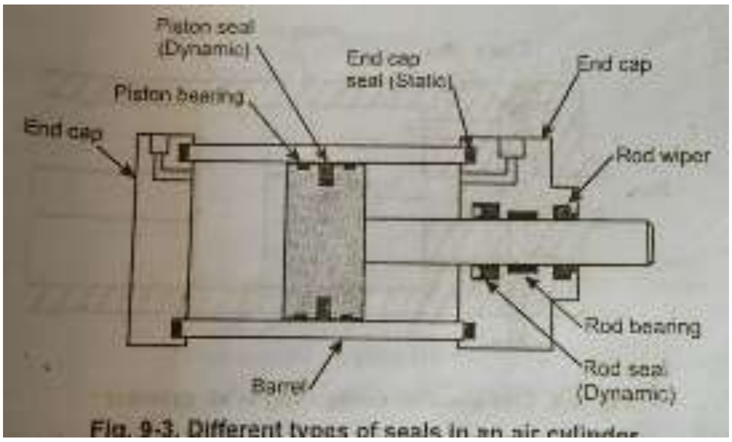
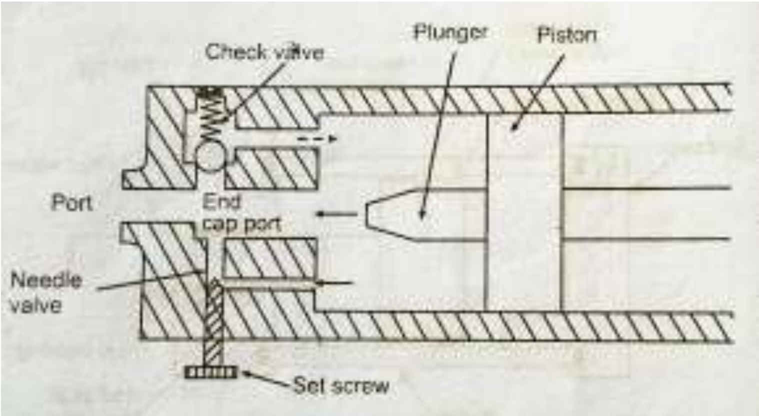


Fig. 9-3. Different types of seals in an air cylinder

1) **Piston Seals:** Piston seals or piston rings are used between the piston and the barrel. These rings can be either metallic or non-metallic. Steel rings coated with zinc phosphate or manganese phosphate give a good life and operate smoothly. Non-metallic rings made of PTFE (polyterafloroethylene), widely known as Teflon is chemically stable and tough. Because of its very low coefficient of friction (0.04), it is ideal in pneumatic cylinders, and can perform well without lubrication also.
2) **Piston Cups:** In some constructions, the piston is provided with piston cup seals. Compared to piston with rings, cup seals are much simpler in design and easy to assemble. They have an L-section, held on either side of a backing plate. For a single acting cylinder one cup is used on the pressure side, while for a double acting cylinder two cups, one on either side are used. The cups are held between the backing plate and retainer clamp. Leather or some synthetic materials are used for sealing cups.
3) **Rod Seals:** Rods are provided with three varieties of seals: (i) a dynamic seal (synthetic material) to prevent leakage of air; (ii) a rod bearing (Teflon) to support the rod in the end cap: and (iii) a rod wiper (synthetic) to prevent entry of atmospheric contaminants. In very dusty environments, rubber bellows are also used to protect the cylinder from the dust and other external particles.
4) **End Cap Seal:** Depending upon the design, either O-rings or die-cut gaskets are used to seal the end cap and the barrel. Synthetic rubbers and leather are commonly used for this purpose.

END POSITION CUSHIONING:

Normal single-acting and double-acting cylinders, while moving heavy loads, may undergo sudden impacts at the end of strokes. This sudden deceleration may cause damage to the load, or cylinder or to the pneumatic system itself. To avoid this problem, end-position cushioning is provided in cylinders.



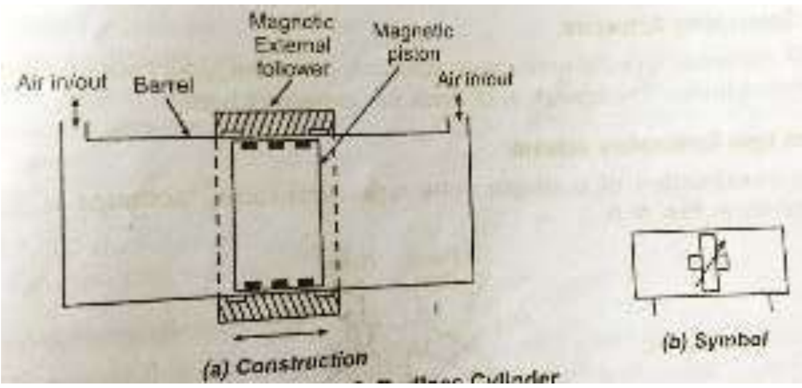
In this, the piston end is provided with a plunger (or a cushioning piston), the air inlet port is such that it matches with the cushioning plunger size. At the end of stroke, the cushioning piston mates with the inlet port and blocks the direct flow path for the air.

The exhaust air now passes through a small, adjustable restricted opening. Since air cannot pass out easily, the restricted flow through small openings provides a cushioning effect to the decelerating cylinder. Thus, in the last part of the stroke, the piston speed gets reduced gradually, which otherwise would have been stopped instantly. The area of the restricted flow path, hence the cushioning effect can be adjusted with an adjustable screw.

For the onward stroke, since the main entry is blocked by the cushioning plunger, a by-pass check valve is provided. The air passes freely through the check valve against a bias spring pressure. During cushioning action (in the retraction mode), the check valve is non-operational, hence no air can escape through it.

RODLESS CYLIDERS:

As the name suggests, these are cylinders without any rod extending from them. A rodless cylinder has a barrel with rodless piston. In some applications, where there is not enough space is available for the rod extension, or where the stroke length required is too high, then rodless cylinders are quite useful.



In this, the piston is rodless, and is freely movable within the cylinder barrel. The piston has no positive/rigid connection to the external member for actuation. The piston has a set of annular magnets fitted around it. The external member/actuator is a magnetic follower, and it is linked to the piston due to magnetic coupling between them. As the piston moves under fluid pressure, the external sliding member moves in synchronisation with it. The load to be moved is mounted on a carriage, which in turn is connected to the magnetic slide. Hence, when the slide moves the carriage along with the load moves in the direction of movement of the piston.

Advantages:

1) The construction of the cylinder is simple as the barrel is sealed from both ends.
2) Such a cylinder has no rod extending from the cylinder and convenient for space contained applications.
3) The cylinder can be used for extreme stroke lengths
4) Flatbed carriages can be used for carrying the loads.
5) The construction can be made compact by concealing the cylinder below the carriage.

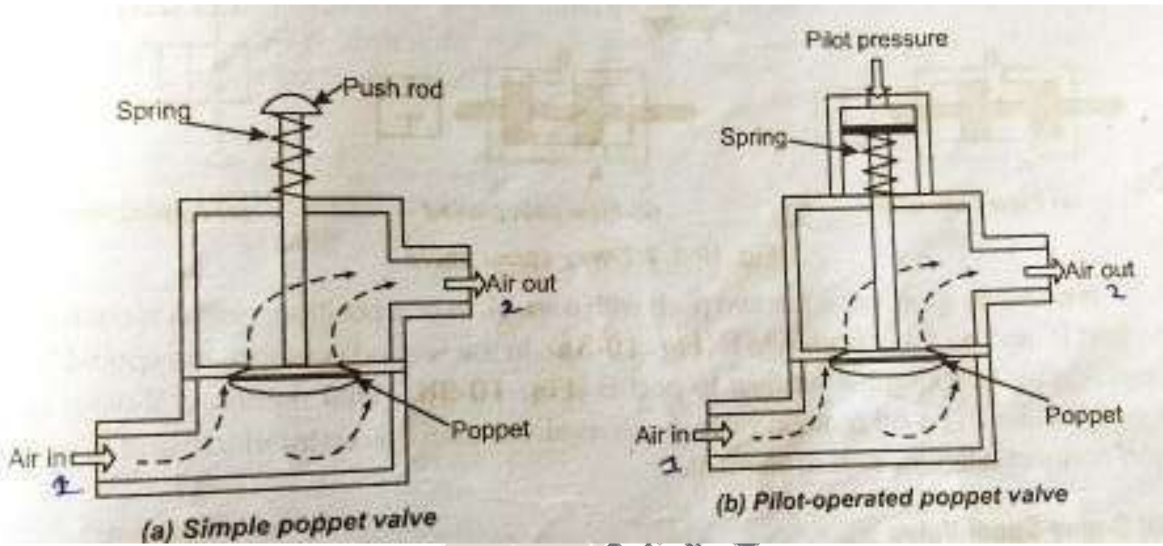
PNEUMATIC CONTROL VALVES

Classification of Pneumatic valves:

1) Direction Control Valves
   a) Poppet Valves
   b) Spool (slide) Valves
2) Flow control Valves
3) Pressure control Valves

4) Non-return Valves
   a) Check Valve
   b) Shuttle Valve
   c) Quick Exhaust Valve

Poppet Valves:



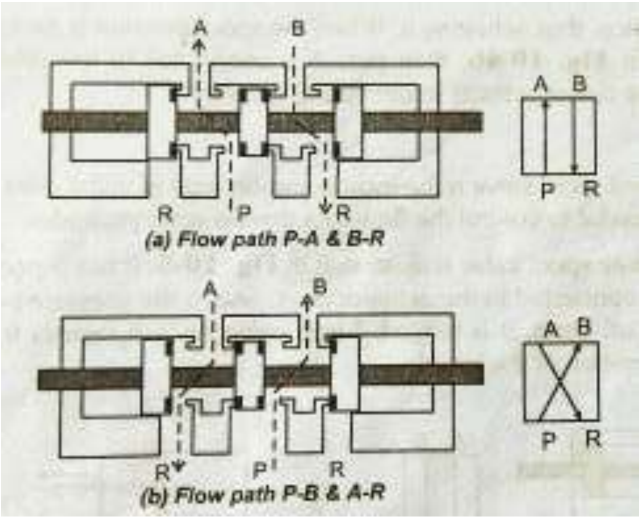
(a) Simple poppet valve (b) Pilot-operated poppet valve

In poppet valves (also termed seat valves) are used to control the air flow. In a simple poppet valve, the poppet is operated manually. It has a cylindrical arrangement with two ports (1 and 2). The ports are separated by a poppet, seated on a valve seat. The poppet is held in a closed position (in the normally closed valve) under the action of a spring. Port 1 is connected to the high pressure air supply, while port 2 is connected to the actuator or other pneumatic device. When the push rod is pressed down against the spring pressure, the poppet opens up from the seat, and allows the air to flow from port 1 to port 2.

In a pilot operated poppet valve, the poppet is moved under the action of a pilot pressure. This has the advantage of remote operation, and also application of higher pressure for large size poppet valves.

Suspended Seat type valve:

It has a suspended disc seat which performs the port opening and closing operations. The advantage of the suspended seat valve is that the sealing can be performed with relatively small switching movement.

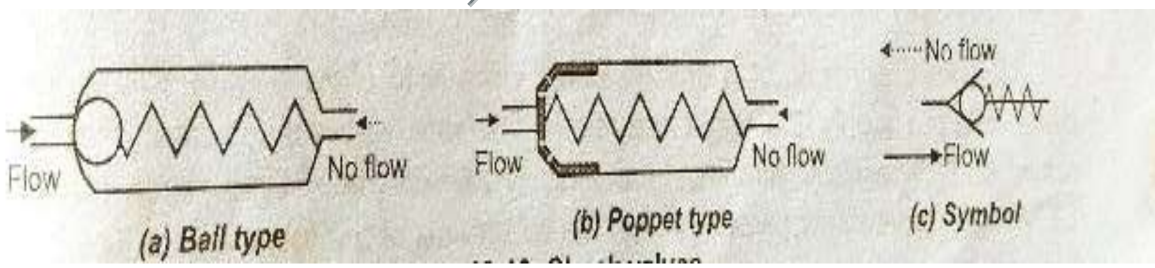


In this the main disc seat seal connects port P to either to port A or port B. The secondary seat discs seal the exhaust port B whichever is not functional. Such valves are generally provided with manual override buttons at each end of the spool to manually move the spool.

NON-RETURN VALVES:

Check valve:

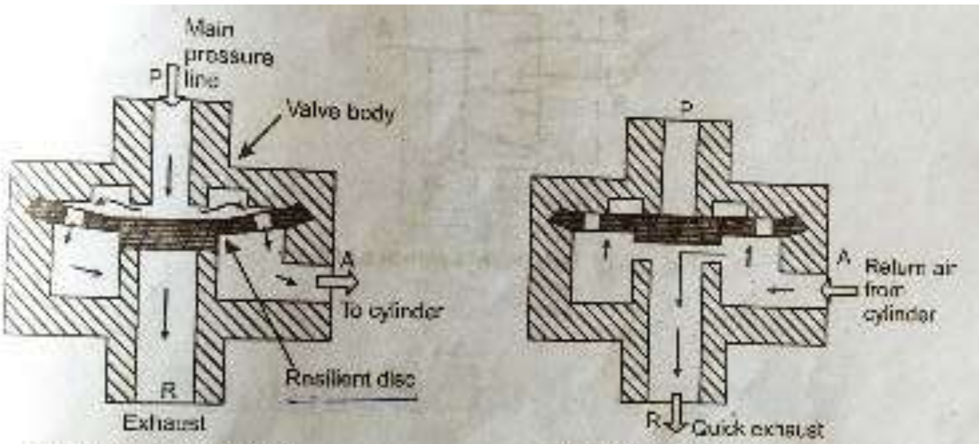
Check valves allow free flow of air in one direction and block any flow in the reverse direction.



The ball and poppet are held under light bias spring pressure against the seat. The valve opens at low cracking pressures in the forward direction and allows the free flow of air. If the air is stopped, the ball/poppet closes the valve under spring pressure and hence do not permit any flow in the reverse direction. Check valves are quite useful in fluid power circuits and are widely used in by pass lines to permit flow in one direction.

Quick Exhaust Valve (QEV):

Quick exhaust valve is a special purpose valve used in pneumatic systems. It is designed to increase the actuation speed of a cylinder, above that of the normal speed by the unrestricted increased flow rate of air.

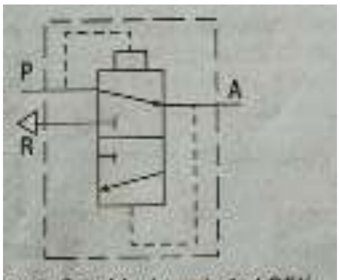


(a) Pressure to cylinder (b) Return from cylinder

The basic principle of a quick exhaust valve is to allow a normal flow to the cylinder in the supply line, while increase the flowrate (above the normal rate) in the return line. It basically eliminates the entry of return/exhaust air through the usual DCV route, where flow passes through the constraints of the tubes and valves.

It consists of a cylindrical body with three ports. The port P is connected to the pressure line (inlet), the port A is connected to the cylinder, and port R is connected to the exhaust. Though all the ports are interconnected, there is an intermediate resilient disc, which allows the flow between only two ports at a time.

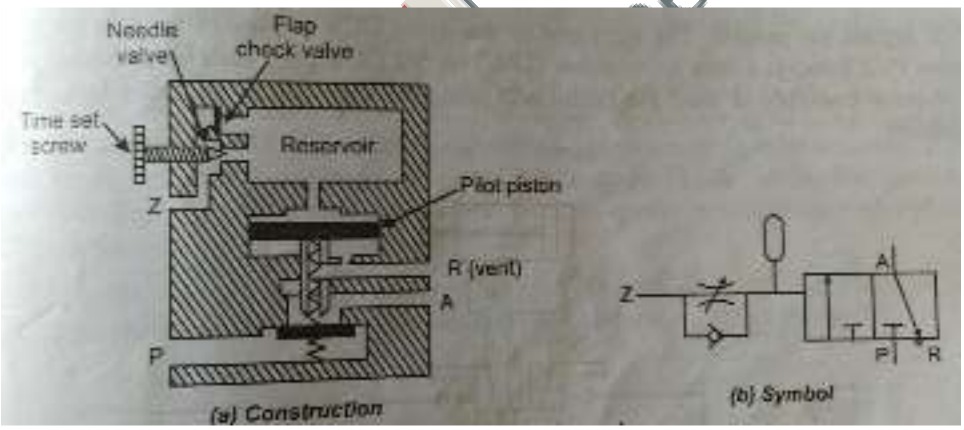
In operation, when the inlet line pressure is applied to the port P, the disc under pressure opens-up to port A, while sealing the exhaust port. The openings in the disc are sufficient enough to allow a normal flow rate from port P to port A, which causes the cylinder actuation at the normal design speed. When the cylinder performs the return stroke the supply line is blocked, because of this resilient disc springs back to its NC position thus blocking the port P. at this position port A allows the return air, by connecting to the exhaust line (R). Since, it gives a large opening between the cylinder return and exhaust port, under spring return (in a single acting cylinder) or under the return line pressure (in a double acting cylinder), the air is exhausted freely through the valve. Due to this unrestricted excess flow rate the cylinder retracts at a higher speed than the normal design speed.



0-13. Graphical symbol of QEV

Time Delay Valve:

The principle of construction of a time delay valve is similar to a 3/2 pilot operated valve. The pilot valve is designed to operate against a spring pressure, once the pilot chamber pressure exceeds the spring pressure. The main valve is held in a closed position (in a NC type valve) by a bias spring. The flow rate can be set by the needle valve screw.



(a) Construction (b) Symbol

In operation, the air is allowed to the pilot chamber reservoir through the needle valve. The reservoir size and the flow rate through the needle valve decide the time required to build-up a pressure in the reservoir. Once the pressure reaches the spring pressure, it actuates the main poppet valve and allows the main line pressure (P) to enter the cylinder port (A).

When the pilot pressure is removed, a flap check valve opens up and the pilot valve is vented quickly to atmosphere. At the same time, the pilot valve retracts under spring pressure, the main poppet valve closes (stopping the air supply from P to A), while the port A us connected to the exhaust line R.

QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS:

DEC 2015/JAN 2016

1) Explain the laws for a perfect gas that governs the compressible nature of air.
2) Explain the basic structure of pneumatic system with its components.
3) Explain briefly with a neat sketch 3/2-way spool type direction control valve.
4) With a neat diagram, explain the construction and the functioning of the spool valve or quick exhaust valve employed in pneumatic system.

JUNE/JULY 2016

1) What are the characteristics of compressed air? Explain them.
2) Sketch and explain structure of pneumatic control system.
3) Sketch and explain rod less cylinder.
4) What are flow control valves? Draw graphical symbols of FCV
5) Sketch and explain construction and principle of operation of a quick exhaust valve.
6) List different types of compressor. Explain with a neat sketch production of compressed air.

DEC 2016/JAN 2017

1) Sketch and explain the cushion assembly for a pneumatic cylinder.
2) Differentiate between hydraulic and pneumatic systems.
3) Write short notes on:
   i) Cylinder mounting arrangement
   ii) Rod less cylinder
4) Explain with a suitable sketch:
   i) Shuttle valve
   ii) Quick Exhaust valve

JUNE/JULY 2017

1) What are the types of pneumatic actuators? With sketch explain the construction and working principle of single acting cylinder.
2) Differentiate hydraulic and pneumatic system.
3) What is cushioning? Sketch and explain the cushioning of cylinder.

4) With a neat sketch and symbol explain 3/2 direction control poppet valve.
5) Explain quick exhaust valve with circuit diagram.
6) Explain the three stages of preparation of compressed air.

DEC 2017/JAN 2018

1) State five disadvantages of using air instead of hydraulic oil.
2) Explain with schematic sketch of FRL unit with ANSI symbol.
3) Explain the characteristics of compressed air.

JUNE/JULY 2018

1) What is cushioning of cylinders? Why cushioning is necessary? Explain the working of a typical cushioned cylinder.
2) Explain the different operational type principles used for the construction of Rod less cylinders.
3) What is the function of a time delay valve? Explain the constructional features of a typical time delay valve with neat sketch.

CRASH COURSE – MAY 2017

1) Give complete classification of pneumatic cylinder.
2) What is an FRL unit? Give the graphic symbol of it.
3) Explain with neat sketch solenoid controlled pilot operated direction control valve.

ONE TIME EXIT SCHEME – APRIL 2018

1) With a neat sketch explain the structure of pneumatic system.
2) Write a neat sketch explain FRL unit.
3) With a neat sketch explain rod-less cylinder.
4) Explain with a neat sketch:
   i) Time delay valve
   ii) Shuttle valve
   iii) Poppet valve
   iv) Solenoid valve

MODEL QUESTION PAPER – 1

1) Sketch and explain the mechanism of end position cushioning.
2) State the advantages and disadvantages of pneumatic systems.
3) Explain the different types of seals with neat sketch.
4) Explain with a neat sketch the construction and operation of a typical quick exhaust valve to increase the actuation speed of a cylinder in a pneumatic system.
5) Explain the working of suspended seat type valve with a neat sketch.

MODEL QUESTION PAPER – 2

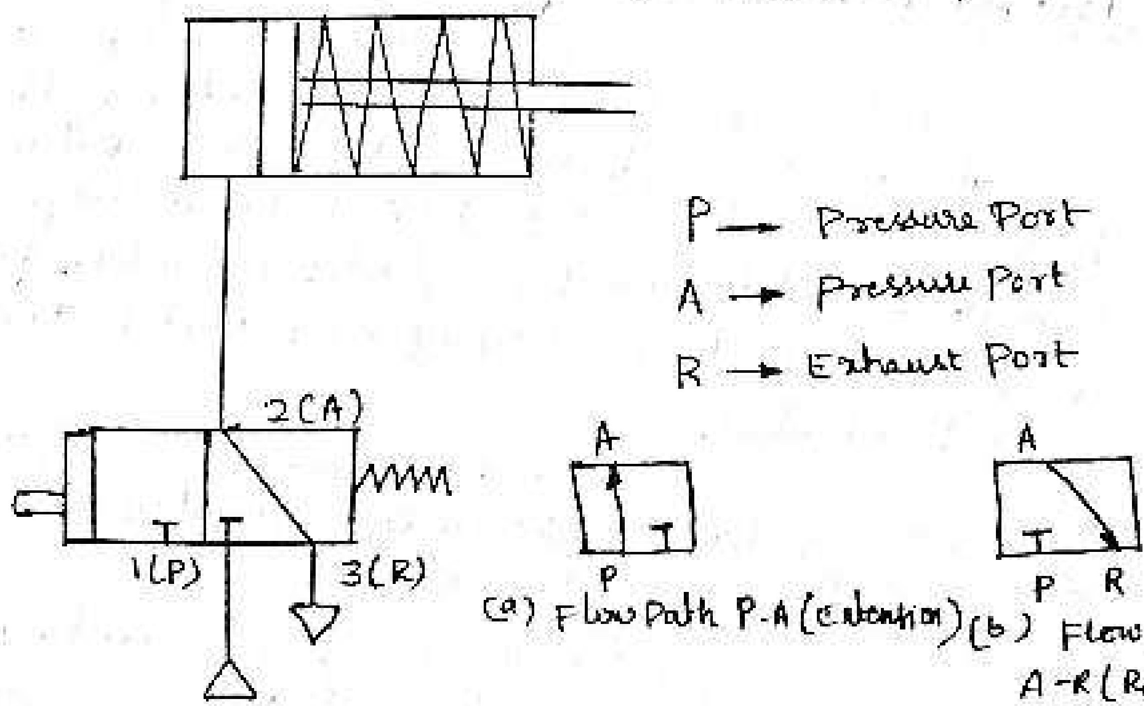
1) Explain the characteristics of compressed air.
2) Explain with a neat sketch the working of single and double acting pneumatic cylinder.
3) Explain with a neat diagram the structure of Pneumatic control system.
4) Explain with a suitable circuit diagram the application of a memory valve.
5) Explain the working of shuttle valve and time delay valve with a neat sketch.

Module-5 : Pneumatic Control Circuits.

Simple Pneumatic Control:

A Pneumatic Control system is built into a Pneumatic Circuit to control and direct the air flow. The first Control element is the air regulating valves, which is set to obtain a flow to achieve the required operating Pressure in the line. Next Comes the master Control Valve, which is nothing but a Directional Control valve (DCV), whose purpose is to allow the the flow to the required Port to cause cylinder actuation. Then the flow Control valves (FCV) are used before the actuator or after the actuator to Control the speed of the Cylinder, the Speed of Cylinders Can be increased by the use of quick exhaust Valves. A quick exhaust valve allows the return-air to escape directly to the atmosphere, without being passed through the DCV route,

Direct actuation of Cylinder



(a) Flow Path P-A (extention) (b) Flow-Path A-R (Retraction)

Fig Direct actuation of Cylinder

In direct actuation cylinder, the cylinder operation is controlled directly by the operation of the DCV. The DCV is directly linked to the cylinder and the DCV in turn is operated by some actuation means like pedal or button. A typical Pneumatic Circuit involving direct actuation of a cylinder is shown in fig.

It has a spring returned single-acting cylinder connected to a 3/2 NC (Normally closed) directional control valve. The DCV in its unactuated position, connects the cylinder port to the exhaust so that the cylinder remains in retracted position. Thus, the operation of the DCV directly helps in actuating the cylinder.

In operation, when the DCV (Normally closed) is actuated, high pressure air flows from Port 1(P) to Port 2(A), keeping the exhaust port in blocked condition. Due to this, the cylinder extends. When the DCV is de-actuated (released), the cylinder Port 2(A) is directed to the exhaust line 3(R). Keeping the 1(P) Pressure port in blocked condition. The cylinder retracts under spring pressure

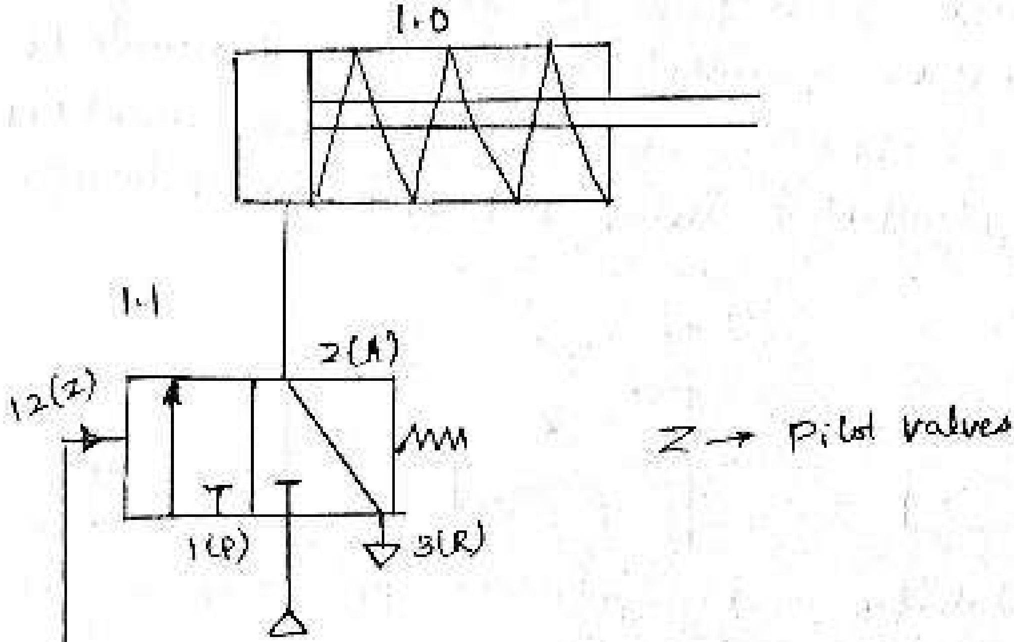
2. <u>Indirect actuation of cylinder</u>

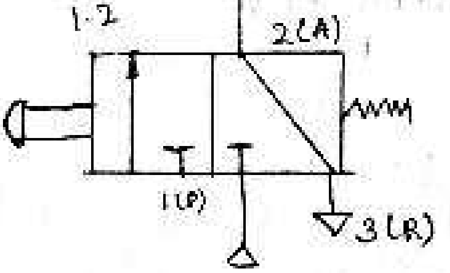
In this case, the DCV is operated by another button operated DCV. The advantage is that small manual force is enough to operate the Pilot valve, which in turn actuates a large size DCV: hence a large size cylinder can be actuated. Since the cylinder actuation takes place due to the indirect operation of the DCV it is termed indirect actuation.

A typical Pneumatic circuit with the use of two 3/2 valves for the indirect actuation of a single acting cylinder is as shown in fig.

It has a spring-returned single acting cylinder connected through a 3-position 2-way (3/2) pilot operated DCV. This valve in turn is operated through a

Push button 3/2 DCV, This Push button valve indirectly actuates the cylinder through the DCV





In operation, when the 3/2 NC Push button valve is operated, it allows a low Pressure air to be directed to the main DCV spool operation. when the spool in the valve operates the spool, the high Pressure air line 1(P) is Connected to the cylinder Port 2(A). this causes the extension of the cylinder.

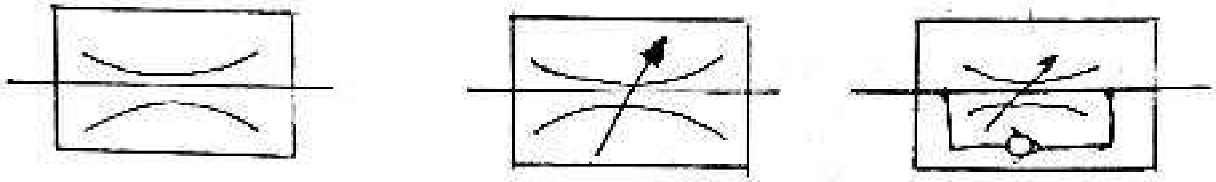
When the Push button is released, the Pilot valve returns, thus closing the low Pressure line and opening the exhaust. Due to this, the spool valve under spring Pressure closes the high Pressure line and opens up the exhaust Port. Because of this, the cylinder retracts under spring Pressure.

3. <u>Flow Control valve</u> (FCV)

In Pneumatic System, flow control valve are used to reduce the flow rate of air in the line and in turn Control the speed of the actuator. In fact, a FCV acts as a restriction to the flow of air by the reduced area of opening.

The opening can be varied, hence the flow rate can also be varied. Most FCVs are adjustable type, so that the flow rate can be manipulated to suit the pneumatic operations.

The Graphical symbols for a FCV (fixed area), FCV (variable area / adjustable) and FCV with a bypass return check valve.



(a) Fixed area type (b) Adjustable area type (c) one-way (check valve) type.

4. Speed Control of cylinder using FCV

The actuation speed of a cylinder can be controlled with the use of FCVs. The FCV regulates the flow rate of air in a pneumatic line, and hence controls the actuation speed. The speed control is possible either by regulating the air at the inlet port while actuation or at the outlet port. These are termed as supply air throttling and return air throttling (Equivalent of meter-in and meter-out controls, respectively in hydraulic power system)

4.1 Supply air throttling

This is similar to the meter-in flow control explained in this. A simple pneumatic circuit using supply air throttling to control the cylinder actuation speed is shown in fig.

In this circuit, a 4/2 DCV with a by-pass check ~~valve~~ type flow control valve is used. The FCV is located in the supply line to the cylinder port 2(A). The FCV is such that in the supply direction the check

Valve closes, and the flow is only through the orifice.

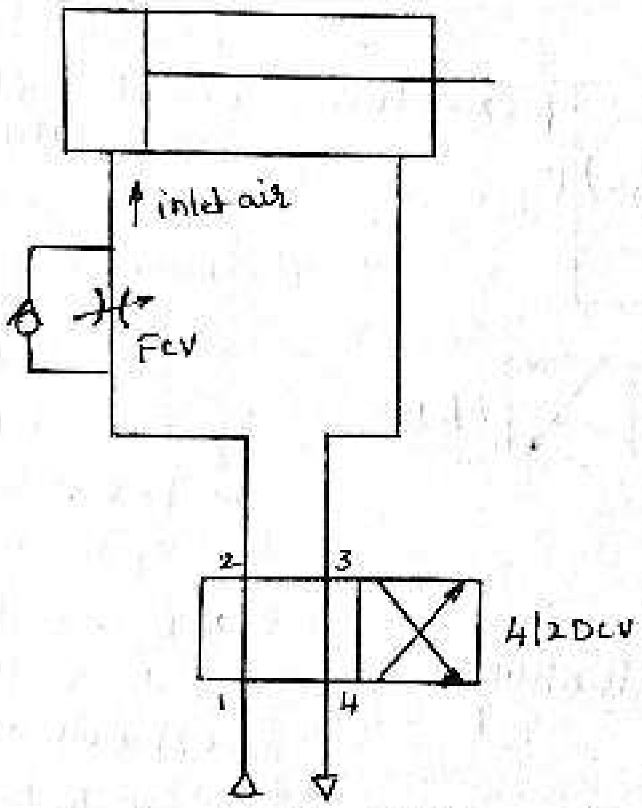


Fig Supply air throttling

In Operation, whe the DCV is actuated, the supply Pressure 1 (P) is directed to the FCV, and then to the cylinder Port 2(A). Since the Check valve blocks the flow, the air has to pass through the restricted orifice opening, thus controlling the flow rate to the cylinder. The cylinder speed will be in Proportion to the flow rate. During this, the return air is exhausted from Port 3(B) to Port 4 (R). Since, the cylinder speed is controlled by controlling the air supply at the cylinder inlet, it is termed supply air trottling.

When the cylinder retracts, the check valve opens up and allows a free flow Path to the air, hence the cylinder returns with full design speed.

4.2 Exhaust air Throttling.

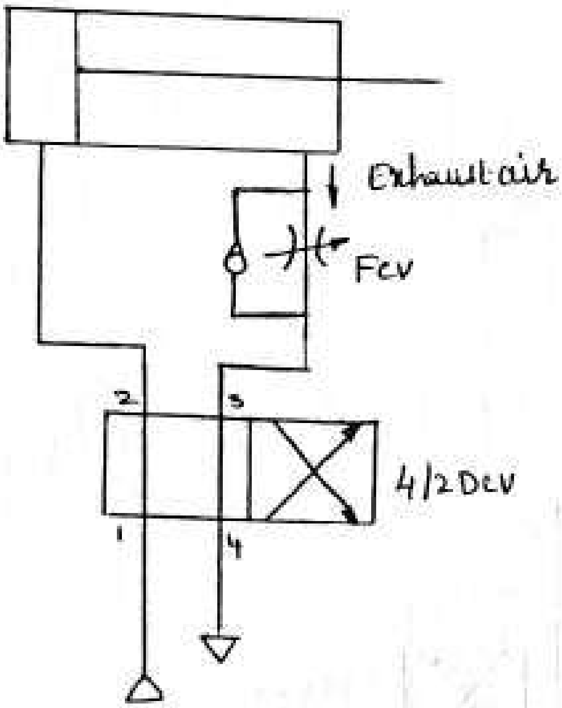


Fig Exhaust air throttling.

This is similar to the meter-out flow control. A simple Pneumatic circuit employing the exhaust air throttling to control the cylinder actuation speed as shown in fig.

In this, a 4/2 DCV with a by-pass check type FCV is used. The FCV is located in the exhaust line of the cylinder Port 3(B). The FCV is such that it completely closes the ball valve in the direction of exhaust such that the air flow has to be only through the orifice opening.

In operation, when the DCV is actuated; the supply pressure 1(P) is directed to the cylinder Port 2(A). It causes the extension of the cylinder. At the same time, the air on the rod end of the cylinder starts exhausting through Port 3(B) via the FCV. Since, in this direction, the ball valve is closed, the exhaust air passes through the restricted opening of the FCV, and flow rate is controlled. This in turn controls the speed of extension of the cylinder. Since, the cylinder speed is controlled by controlling the air at the exhaust line, it is termed exhaust air throttling. When the cylinder has to be retracted, the air flow easily passes through the check valve without any restrictions. hence the cylinder retracts with its full design speed.

Signal Processing element

Pneumatic signal Processing involves the use of Pneumatic logic elements. Pneumatic logic uses air valves and other Pneumatic devices for various Control actions. These Control actions are then applied to Power systems to obtain the required actuation. In Pneumatic logic devices, a minimum amount of Pneumatic force is required, which send Signals to power devices that operate with high Pressure Control valves.

"Advantages of Pneumatic logic devices over electrical logic devices"

1) They are simple by design and fabrication
2) unlike electrical devices, Pneumatic logic devices do not undergo Self destruction under extreme Pressure and heat.
3) They are quite safe and Convenient in explosive environments
4) They have longer life of operation
5) They are highly reliable
6) They have a faster response time (10-12ms) as Compared to electrical relays (50-60 ms) and Solenoids (15ms)

LOGIC GATES

In Pneumatic logic operations, logic gates are used. The five basic logic gates in use are AND, OR, NOT, MEMORY and TIME gates. The use of AND and OR gates with Practical applications in described below.

There are two types of Pneumatic logic devices moving - Part logic (MPL) and non-moving Part logic devices. MPL devices use Spool and Poppet valves as the pilot valves to generate the signals, while non-moving logic ~~ate~~ uses miniature devices based on the dynamics of small steam or air. The logic gates discussed here are based on MPL devices.

OR Gate

In an OR logic circuit, if any one of the several signals is present at the input, it produces an output signals. Hence, all the input signals should be absent for the output signal to be absent. A typical OR gate with the use of DCVs in parallel is shown in fig.

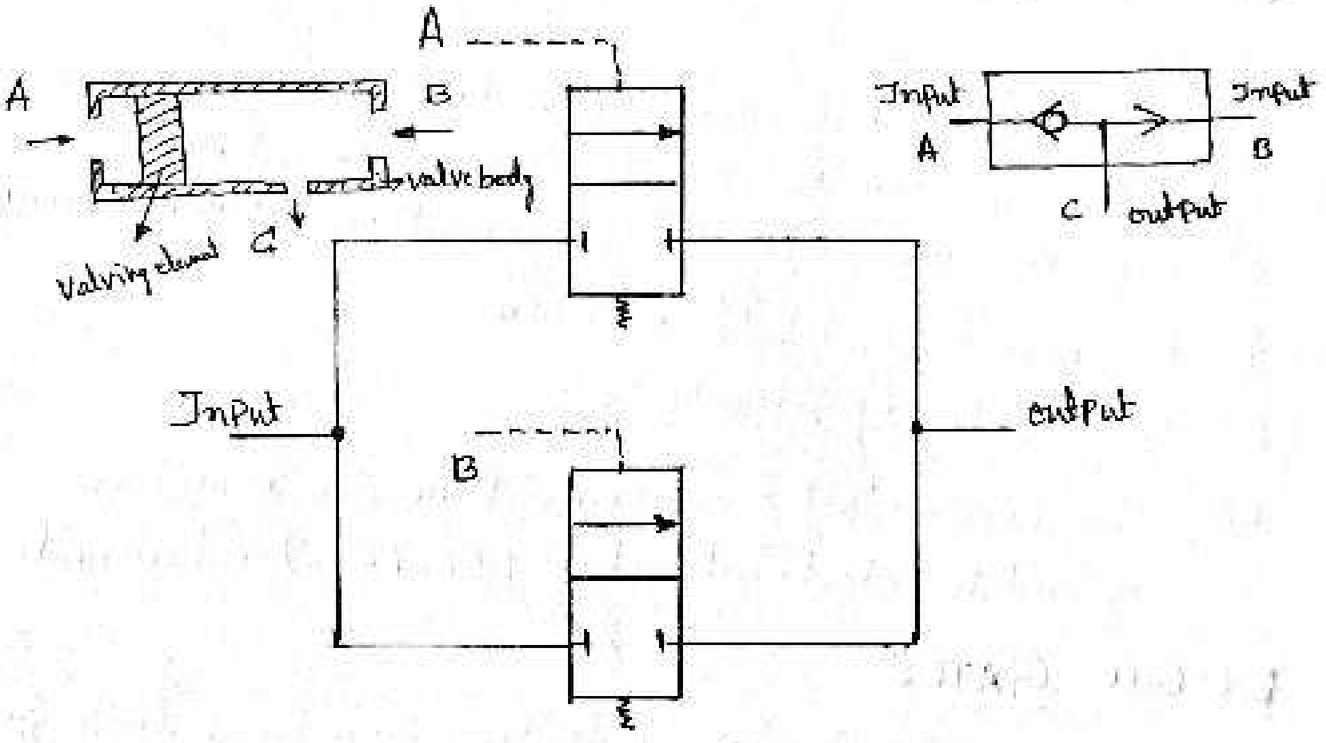
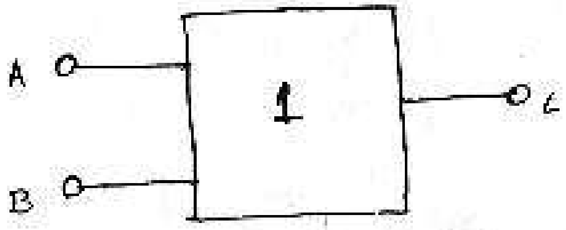


Fig OR logic gate.

In this logic circuit the DCVs are stacked in parallel. The 2 DCVs are connected in parallel in this example. If the input signal is provided to any one of these DCVs, it produces an output signals.

In another design, OR logic can be generated using a shuttle valve. For example, in the OR logic shown in fig the input from any one of the pilot valves to shuttle valve produces an output, which in turn actuates the main DCV.

The Symbolic representation of OR logic and the truth table for two inputs A and B, and the output C is as shown in fig.



(a) OR Logic Symbol

Input		output
A	B	C
0	0	0
1	0	1
0	1	1
1	1	1

(b) Truth table.

The truth table Clearly indicates that when all the inputs are absent. there is no output signal: while any one or both the input signals are Present, it gives an output signals.

Practical examples involving the use of OR logic

(Or)

Actuation of double acting Cylinder using OR logic.

A typical Pneumatic Circuit with OR logic using a Shuttle valve is as shown in fig.

This Circuit is designed to actuate a double acting cylinder using a 5/2 D.C.V. The actuation of DCV takes place by the signal received from any one of the two Pilot valves. A Shuttle valve is placed at the junction between the two 3/2 Push button Pilot valves.

In operation, when one of the Pilot valves is actuated by the Push button, a signal is input at the X or Y side of the Shuttle valve. Input

P – Pressure Port

A – Signal output

S & R – Exhaust port

B – signal output.

Z = Pilot line opens 1 to 2

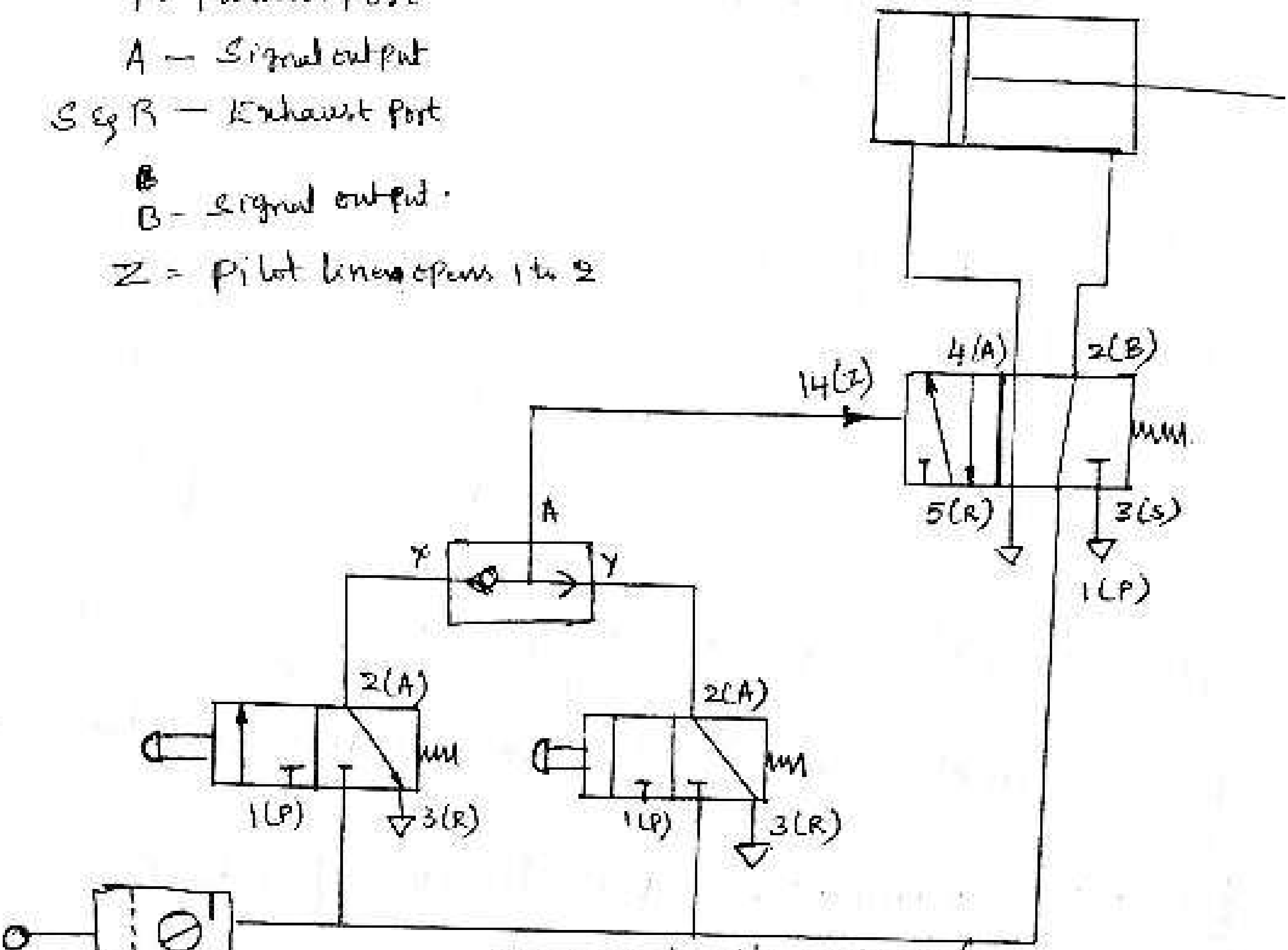


Fig Circuit with OR logic

from any one signal generates an output signal A at the shuttle valve and this Pilot signal actuates the main DCV, Causing the Cylinder extension. Upon release of this Pilot signal (by the release of Push button), the 5/2 DCV returns to its normal Position under spring Pressure, which causes the Cylinder retraction.

AND Logic :-

In an and logic function, two or more input signals must be Present to obtain an output signal. If one of the input signals is absent, the output signal is also absent. A typical AND logic function using two DCVs is shown in fig below.

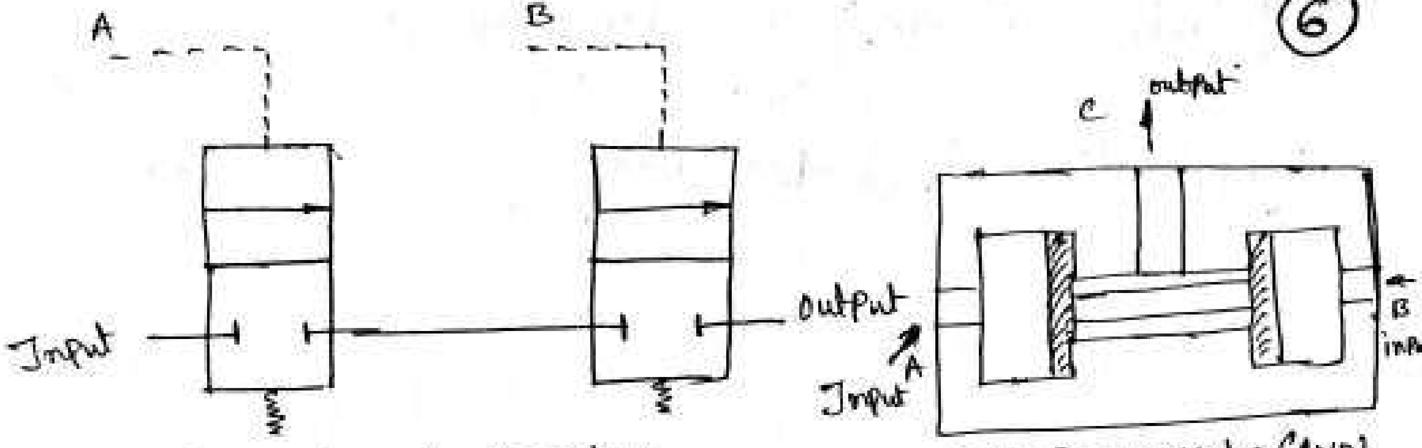
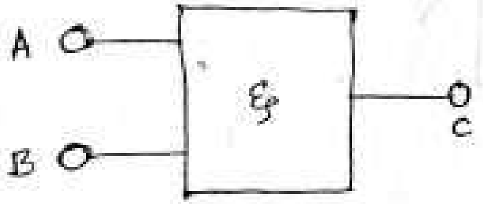


Fig AND logic gate.

In this, two DCVs are connected in series, and the supply pressure in input at the first DCV. Now for the output signal to be present, both the input signals at the DCV must be present. That means unless both the DCVs are actuated, there is no output from the system.

The symbolic representation of AND logic with the truth table for two input signals A and B, to produce output C is as shown below.



(a) AND logic symbol.

Input		output
A	B	C
0	0	0
1	0	0
0	1	0
1	1	1

(b) Truth table.

Fig AND logic symbol and truth table.

The truth table clearly shows that the output is zero when one of the input signals A or B is absent. The output signal is generated at C only when both the input signals A and B are present.

Practical example involving the use of AND logic

(Or)

Actuation of double acting Cylinder using AND logic

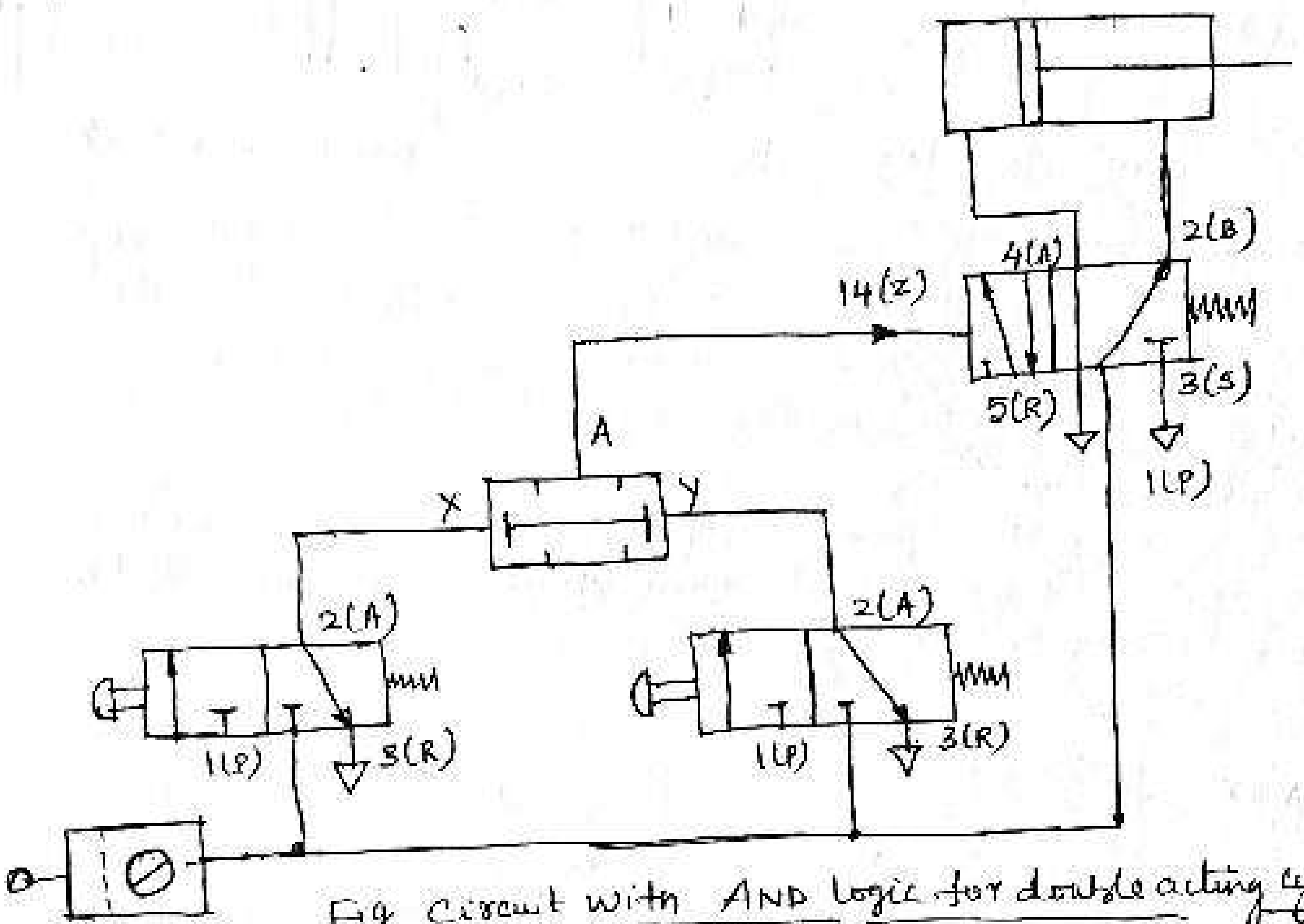


Fig. Circuit with AND logic for double acting cylinder.

A typical Pneumatic circuit based on AND logic function using a two-pressure valve as shown in fig above.

A two pressure valve requires input force on both sides of the spool so that it remains open. If the pressure is absent on any of the sides, the valve remains closed.

In this circuit, the two-pressure valve is connected to the junction between the two 3/2 push-button pilot valves. The output from the two-pressure valve (which acts as the AND logic) actuates the 5/3 DCV and supplies pressure for cylinder operation.

In operation, when one of the Pilot Valve gives a signal to the two-Pressure valve, it generates signal at the X or Y sides. This signal is blocked by the two Pressure valve. as it is unbalanced. If the second signal from the other 3/2 Pilot valve is given to the two - Pressure valve, the valve comes to a neutral Position and Produces a signal output A. This Pilot signal actuates the 5/3 DCV and in turn operates the cylinder.

A typical example of AND logic function is the Control of a hydraulic Press. In this, one Pilot signal is from the manual operation button. while the second Pilot signal is from the Press guard. unless both the signals are Present there is no output signal, hence DCV is actuated, unless the safety gaurd is closed the second signal is not Produced and the DCV remains closed, hence the Press does not operate.

Multi - cylinder applications

Many industrial applications make use of multiple air cylinders to Perform a single job. The main Purpose of using multi-cylinders is to increase the load operating capacity, Perform Clamping operation, Carry-out Sequential operations, and so on. Multicylinders are also used when the use of a single cylinder Cannot meet the required application, special Pneumatic circuits are designed using various DCVs and Pneumatic logic functions to Perform the required operation: such as coordinated motion, sequential operation, Cascading and so on. Some of the basic multi-cylinder Pneumatic circuits and their applications are briefly discussed below.

In any fluid application, Circuit diagram are drawn using different hydraulic or Pneumatic elements. They are then tested with simulation tool to check whether each element in general and the system as a whole is functioning satisfactorily as per the design of the system.

But in multicylinder application, the Circuit alone may not be sufficient to adequately represent the functional sequence of each of the cylinder or the inter-relation between the cylinders. The functional sequence and inter-relation between Cylinders can be best represented and understood with the help of a functional diagram.

Functional diagrams are means of representing the functional sequences of different Controls such as mechanical, electrical, electronics, Pneumatic and hydraulic, as well as Combinations of these control such as electropneumatic, electro-mechanical, electro-hydraulic etc.

The main objective of a functional diagram is to project a clear and distinct sequence of operations of all pneumatic elements used in the Pneumatic circuit.

Functional diagrams are of two types. They are

a. Motion or Movement diagram
b. Control diagram.

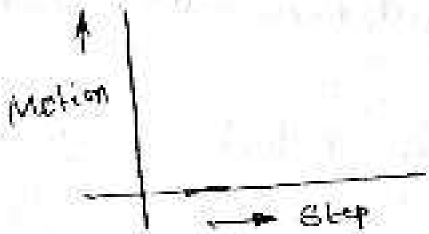
Motion Diagram

Motion diagram is a graphical representation of Conditions relating to working elements or Components. Varieties of motion diagrams are used in engineering Control system. Motion diagram can be drawn in a single co-ordinate system or in two Co-ordinate system. However two co-ordinate system gives a better understanding and clarity, and hence commonly adopted.

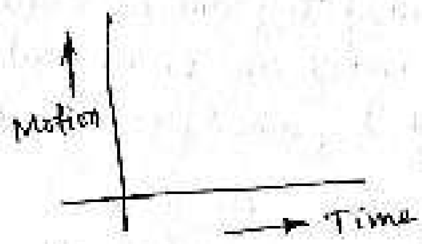
Motion diagrams are drawn for two variables of the working element such as step and time. Correspondingly the diagrams are called

a. Motion - step or Displacement - step diagram

b. Motion or displacement - time diagram.



(a) Motion - step diagram



(b) Motion - time diagram.

Fig Concept of motion diagram

Illustrate motion control diagram for a 2-cylinder circuit.

(07)

Illustrate function - diagram for double acting, two cylinders for a sheet metal bending applications.

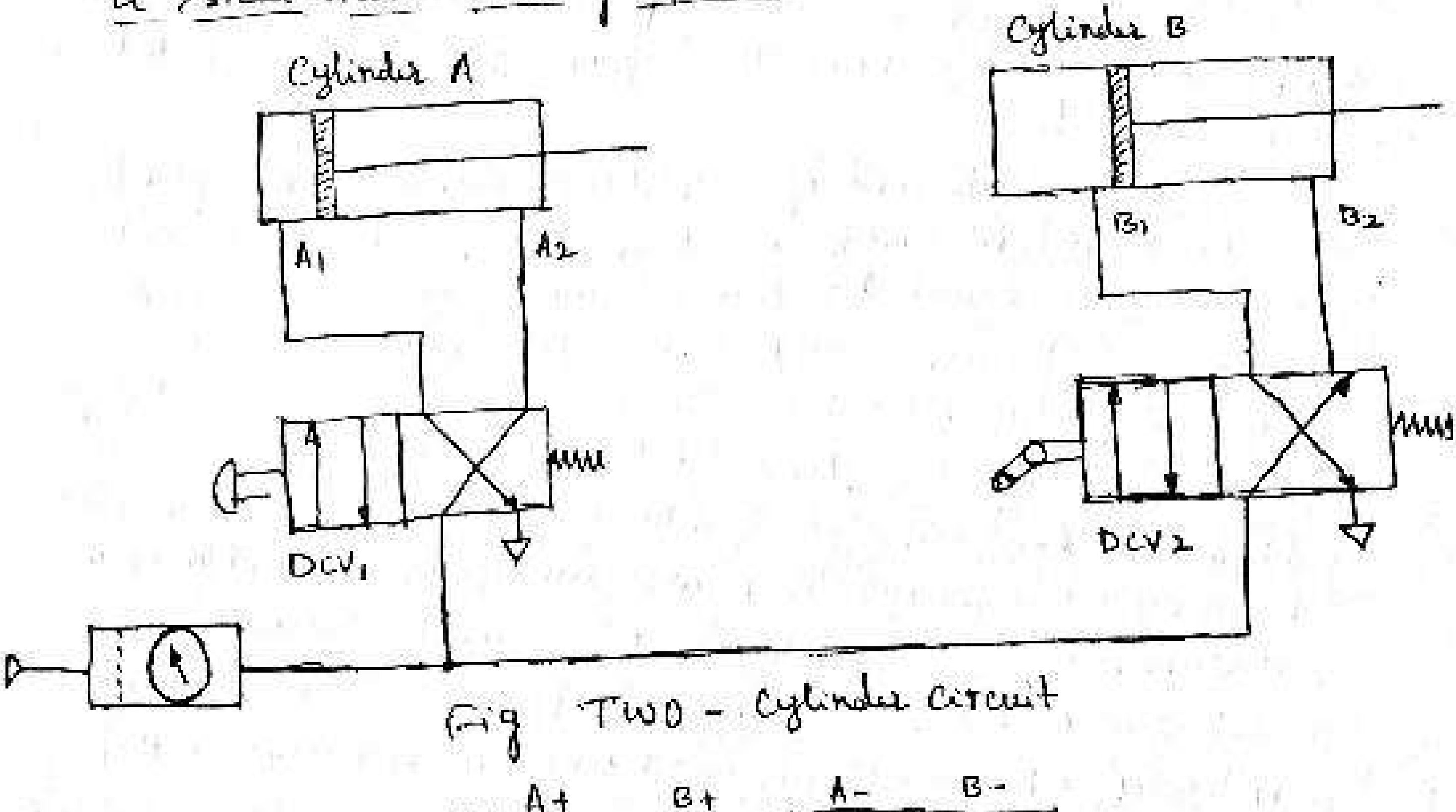


Fig TWO - Cylinder Circuit

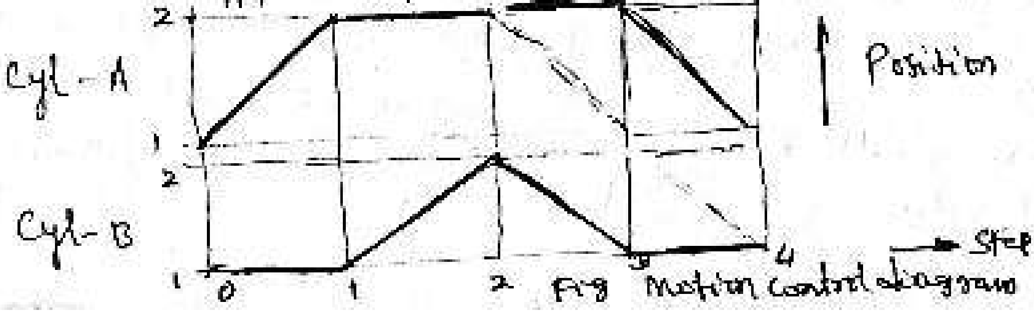


Fig Motion control diagram

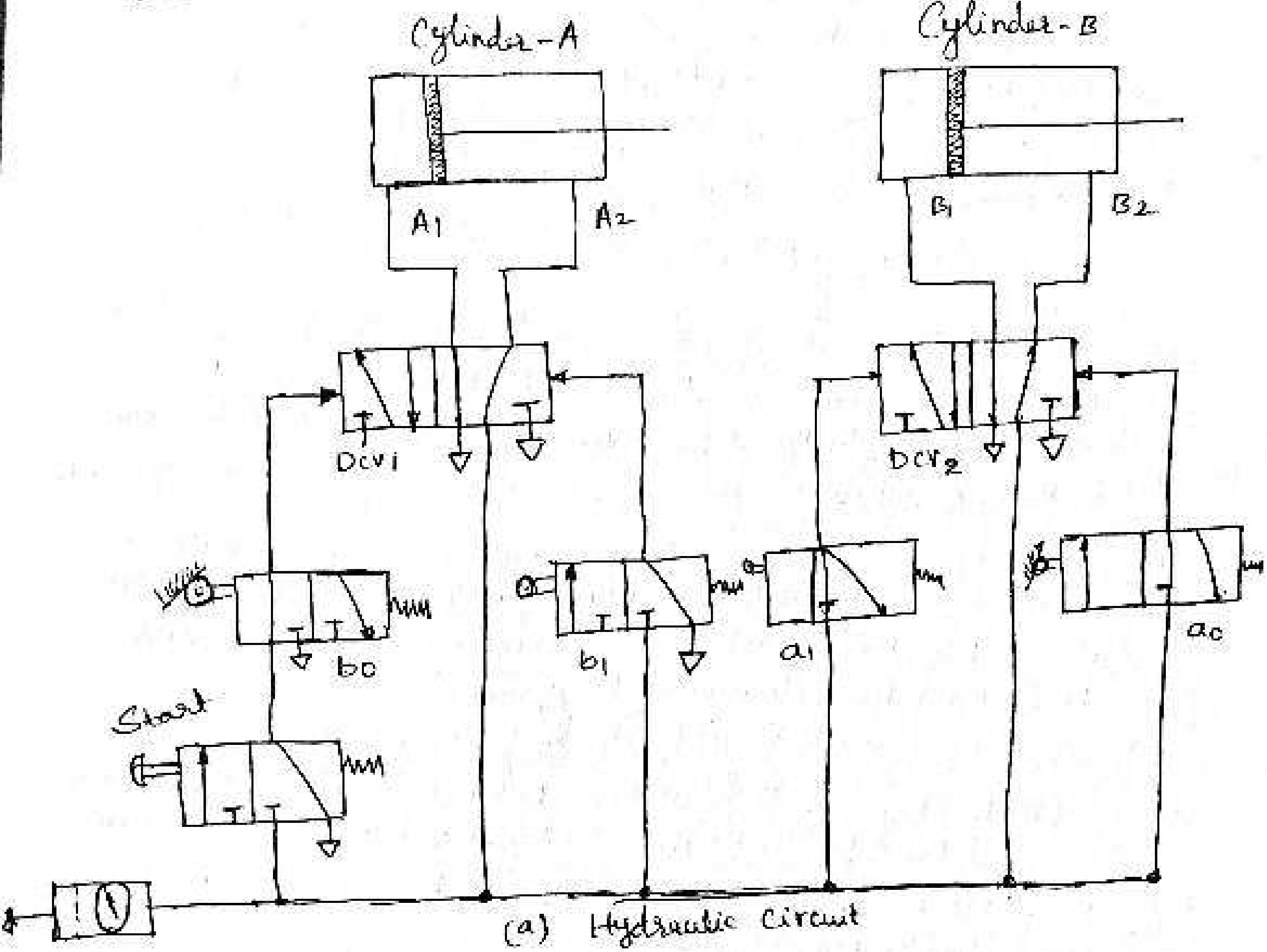
In this circuit, the cylinder A activates ~~a limit switch~~, ~~which~~ at its initial position 0 by the operation of push-button of DCV, supplying air pressure to port A_1. This causes the cylinder A to under go extension (A+). This extension will be used to clamp the work piece. this is indicated by the thick diagonals line on the motion control diagram of cylinder A. During this the cylinder B remains stationary and is indicated by thick horizontal line on the motion control diagram of cylinder B.

At the end of extension, cylinder A activates a limit switch, which in turn activates the DCV_2, supplying air pressure to port B_1 of cylinder B causing its extension (B+). This extension is used for to bend the work piece. This is indicated by the thick diagonal line between steps 1 and 2 on the motion-control diagram of cylinder B. Immediately after its (cylinder B) complete extension, another limit switch is operated that releases the DCV_2 to its normal position under spring pressure, there by supplying air pressure to port B_2. This causes the cylinder B to retract (B-). This is indicated by the thick diagonal line between step 2 and on 3 the motion control diagram. This is used for withdrawing of bending tool.

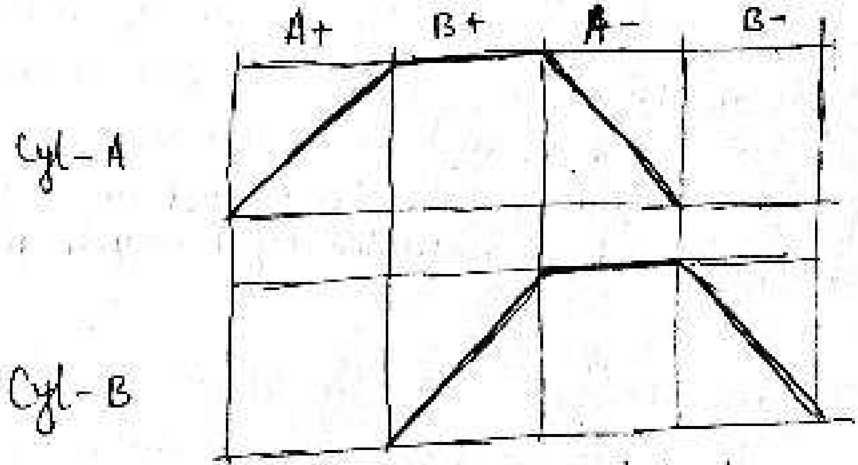
At the end of completion of retraction, the cylinder B operates a limit switch, which de-energies the DCV, so that air pressure is supplied to port A_2 causing its retraction (A-). This causes release of work piece. ~~by~~ This is indicated by a thick diagonal line between step 3 and 4 on the motion control diagram of cylinder A. The thick horizontal line between step 1 & 3 on the motion-control diagram of the cylinder A, indicates that it remained stationary when the cylinder B was undergoing both extension and retraction. Similarly, the cylinder B remained stationary, when the cylinder A was undergoing extension and retraction. which is indicated by the thick horizontal lines on the motion control diagram between steps 0 and 1, and steps 3 and 4, respectively.

Thus, motion control diagrams are useful in multi-cylinder circuits to understand the sequence of operation of different cylinders.

Coordinated motion Control



(a) Hydraulic Circuit



(b) Motion Control diagram

Fig Simple two-cylinder Circuit.

In a Coordinated motion Control, the multi – cylinders operate in such way that there is no conflict between the opposing pilot signals across the DCVs. For example, in a simple two cylinder circuit, where the first cylinder (A) Completes its cycle before the second cylinder (B) Complete its cycle. A typical two-cylinder circuit of this example is as shown in fig above.

The functioning of this Coordinated motion Control circuit is as follows.

(a) The valve b0 gets the start signal, actuated by cylinder B at rest, and sends a pilot signal to DCV1. This causes extension of cylinder A (A+ on the motion – Control diagram) Cylinder A actuates, as there is no opposing signal from valve b1.

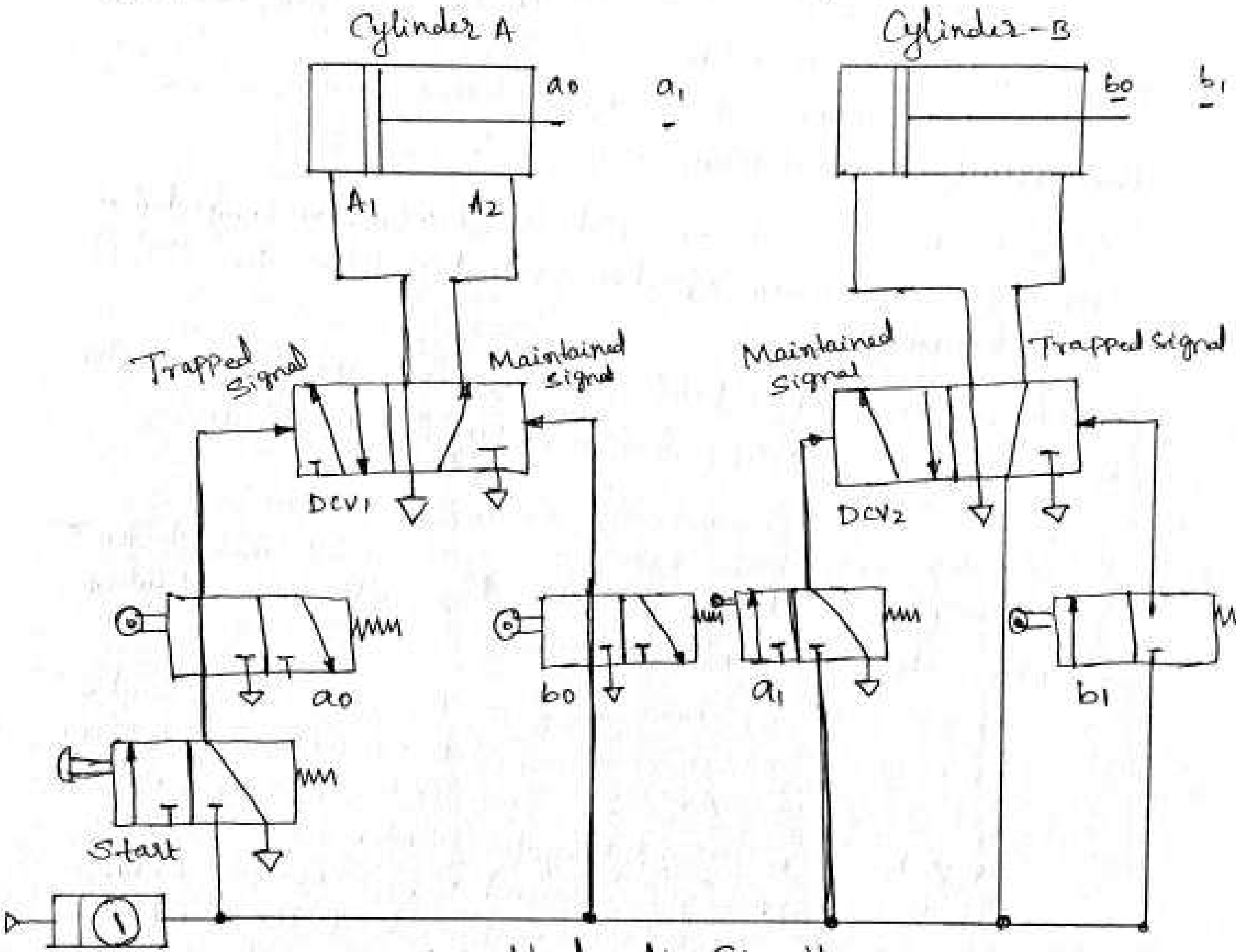
(b) When Cylinder A hits the limit switch of a1, the valve a1 actuates DCV2 which supplies air pressure to cylinder B. is free to extent as it has no opposing signal from valve a0 (B+ on the motion Control diagram)

(c) When cylinder B hits the limit switch of b1, the valve b1 actuates DCV1 to its right position envelop, which supplies air pressure to retraction of cylinder A. Cylinder A retracts freely because valve b0 is not actuated. This movement is indicated by A- on the motion Control diagram.

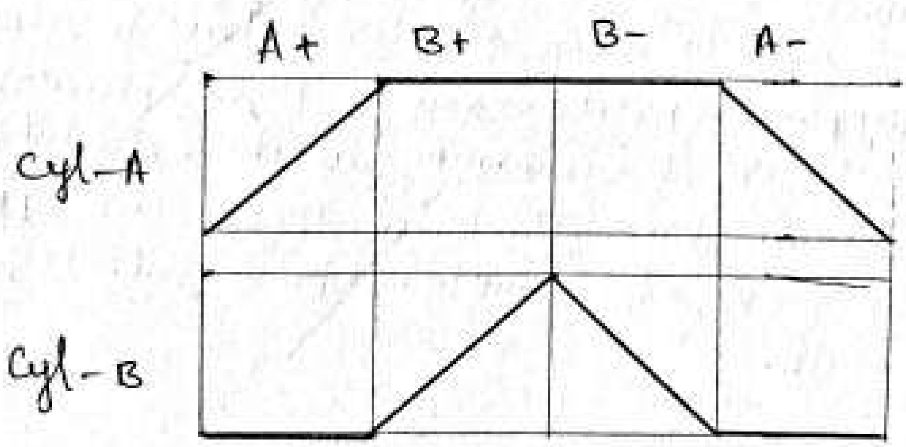
(d) When cylinder A retracts completely, it hits the limit switch a0, and in turn a0 sends a pilot signal to DCV2 to allow air pressure to cylinder B to undergo retraction. Again, cylinder B undergoes free retraction as there is no opposing signal from valve a1. This movement is indicated by B- on the motion-Control diagram.

(e) When Cylinder B retracts Completely, it hits the limit switch b0, which actuates valve b0. This, in turn, sends a pilot signal to DCV1 to send air pressure to cylinder A. Then, it becomes a start signal to start the new cycle for the cylinder operation as explained in the above steps.

Sequential Motion Control - Signal elimination



(a) Hydraulic Circuit.



(b) Motion Control diagram

Fig Ineffective Circuit in Sequencing.

In some sequential operations where the function of one cylinder is enclosed within the function of another cylinder, the signals remain active and lead to conflicting signals. These are termed trapped signals and maintained signals due to which the circuit does not work as desired.

A maintained signal is a pilot signal which has completed its function and remains effective so that it blocks the effect of other signals.

A trapped signal is a pilot signal ~~operated~~ applied to a valve with an opposing pilot signal remaining still effective.

As shown in fig an ineffective cylinder sequencing circuit. The circuit does not function due to the presence of trapped and maintained signals. Two situations can be noticed from the circuit:

(a) When the start signal is passed to valve a0, actuated by the cylinder A at rest, it sends a pilot signal to DCV1 to extend cylinder A. However, cylinder A cannot extend since valve b0 is actuated by the cylinder B at rest. This results in an opposing pilot signal to be applied to DCV1. hence no actuation takes place. Thus, due to the maintained signal of b0, the a0 signal gets trapped resulting in nil action.

(b) Similarly, when cylinder B tries to retract b1, it applies a pilot signal to DCV2. However, since the cylinder A remaining at its extended position actuates valve a1, which applies an opposing signal to DCV2, thus nullifying the signal. Hence, no actuation results.

Cascade Control action

Principle of Cascade system :- Cascade is simple and most effective method to eliminate the maintained and trapped signals is the use of cascade Control action. In a Cascade system, the circuit is divided in to different zones in which the air supply is latched by additional DCV. The Principle of a Cascade system is as follows.

1. Follow a simple design Procedure to determine the minimum number of groups in the Circuit. To eliminate the trapped signals, allocate the signal valve (Limit switches) between these groups.
2. Unlike the Previous Circuits where a single supply bus bar was used to carry the main supply pressure to all Components, in a Cascade system a separate supply bus bar is Provided to each group.
3. Provide a Conventional arrangement of Selector Valves to direct the supply only to the active group.

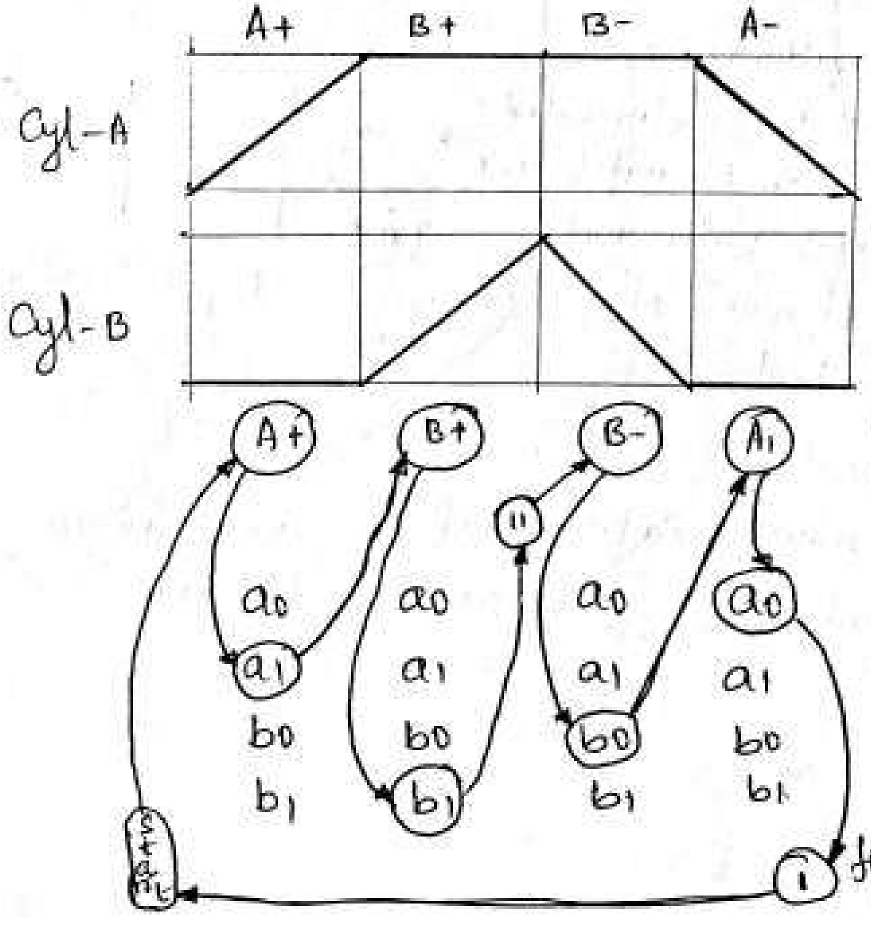


fig Cascade Circuit design.

~~Cascade circuit design~~

Signal elimination Technique.

In this technique it is Possible to eliminate signals either mechanically or by means of suitable Circuitry.

Mechanical Methods

In this method the signal elimination is by means of (a) Short impulse transmitter or (b) Idle return roller.

Short impulse transmitter method is composed of DCV with Overcentre function and the respective type of Control. when using such a type of valve one should have the following Points

(a) The operating reliability depends to a great extent on the speed of actuation (max 0.1 to 0.15 m/sec)

(b) The valve is actuated in the middle part of the Stroke and not at the ends of the stroke. That is the actuator must be operated as far from the stop, otherwise a Continious signal will exist.

Idle return roller can be used if the signal to be eliminated is Provided by a limit switch. The use of roller lever Valves with idle return to eliminate signal overlapping has the following disadvantages

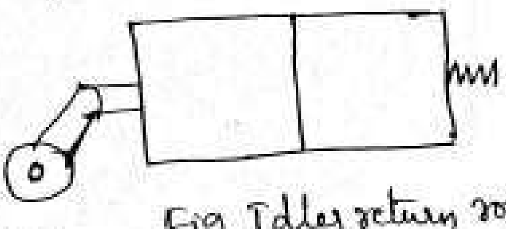


Fig Idler return roller

(a) The end Position Cannot be sensed accurately

(b) Function may be impaired due to Contamination

(c) Fast Control of Systems are not Possible..

Electro-Pneumatic Control

The valves used as intermediate devices between the Pneumatic Power source and actuators are the control elements. Infact, these valves can be operated by various means such as manual, electrical and mechanical methods. Certain actuators (such as Pneumatic cylinders) may also use some electrical means to limit/control their movement. when an electrical means used as a mode of actuating the Pneumatic valves (to control the actuators) such systems are termed electro-Pneumatics system.

Two Popular equipments that are widely used in electro-pneumatic systems are electro-pneumatic valves and Pressure switches.

The main advantage of electro-Pneumatic system is the case of control/actuation even at remote locations in plants and machineries. The switch to supply the electric-current for actuation of the system is kept at an accessible point.

Solenoid is the most common element used in electro-Pneumatics for actuation. Solenoid is a electromechanical system, which uses Push button switches, relays, Contactors and limit switches for its operation.

Direction Control valves used in Pneumatic Power systems are solenoid controlled, and are the most common electro-Pneumatic devices used in industries and machine tools.

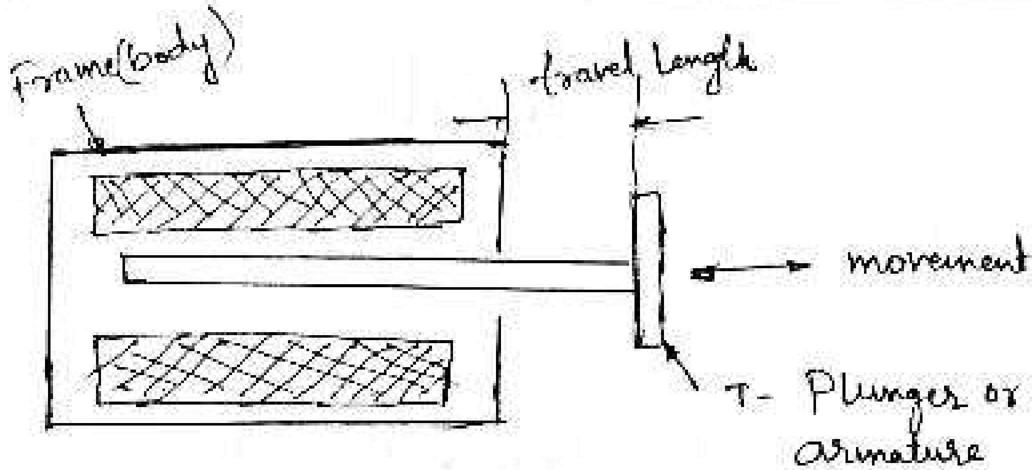


Fig 13-1 Solenoid

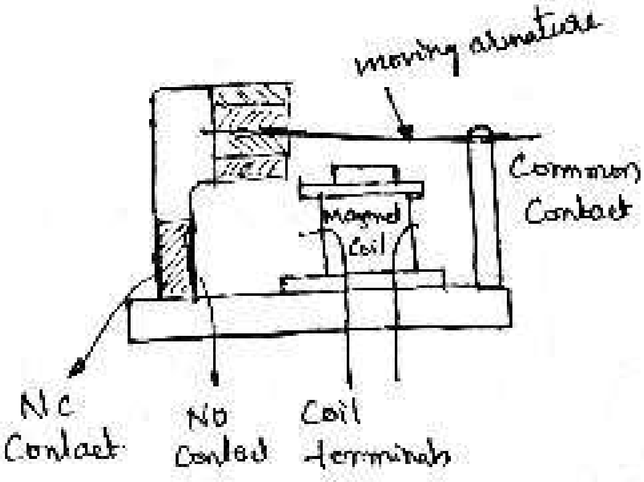
Basically a Solenoid is nothing but an electromagnet, which is electromechanical device. An electromagnet is a temporary magnet that gets energised when an electric current is passed, and de-energised when the current flow is stopped. thus, it converts electrical power to mechanical force and motion through an armature. The construction of a typical solenoid is schematically illustrated in fig

It consists of an electrical coil, an armature (usually a T-plunger) and a cylinder in which the coil is wound on a bobbin and located in the cylindrical frame.

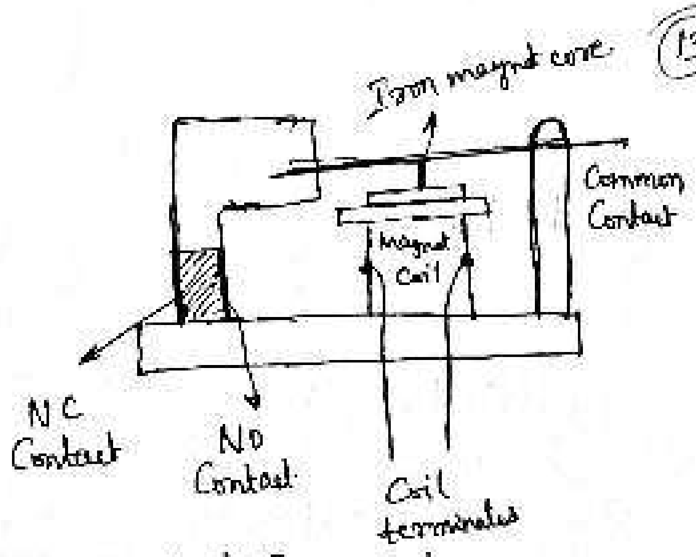
In operation, when an electric current is passed through the coil, a magnetic field is set up. Normally the armature is kept in extended mode under spring pressure. Due to the magnetic field the plunger is pulled inside the coil. The plunger, which is connected to a directional control valve in turn operates the valve, thus controlling the flow path of the air.

Relay

Electrical relay is another electromagnetic device. It is basically actuated switch. The relay uses a small current magnet to operate the contacts to control a large current in the circuit. The construction and operation of an electric relay is illustrated in fig below.



(a) De energised



(b) Energised.

Fig Electrical Relay.

It Consists of a magnetic Coil, a moving armature and a set of electrical Contacts. when a Current flows through the Coil a magnetic field is generated, which in turn attracts the armature. This Causes the internal Contacts to change Position (open to closed, or closed to open). For the relay shown in fig. there is one normally open (NO) and one normally Closed (NC) set of Contacts. when the Coil is de-energised, the Contacts are are in closed Position fig(a). That means, there will be a Condinions flow of current through the switch and the device is activated. when the coil is magnatised (energised), the armature under attraction breaks Contact with the NO Contact. thereby cutting the supply to the System Fig(b). please note that a small electrical signal to the magnetic Coil actuates the switch, which in turn Controls the supply to another actuating device like a valve or drive motor.

Applications of Relays

1) Beaking of the Control Circuit from the main Circuit
2) Delaying and Conversion of signals. and multiplication of Signals

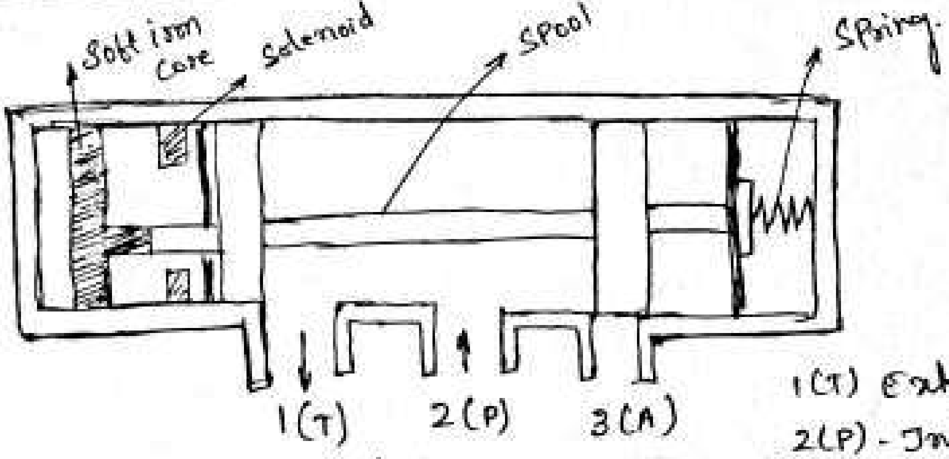
Contactors :-

Electrical Contactors are Control elements that are used to make or break the Circuit in ~~electromagnetic~~ Pneumatic and other electrical systems. Basically these are made of highly Conducting materials like Copper or brass. The selection of suitable Contactor in ~~electromagn~~ Pneumatic system depends on the type of operation, reliability, location, Space availability, and so on. The Contactors form the Point of Contacts in switches (such as single Pole, and so on)

Applications of Contactors

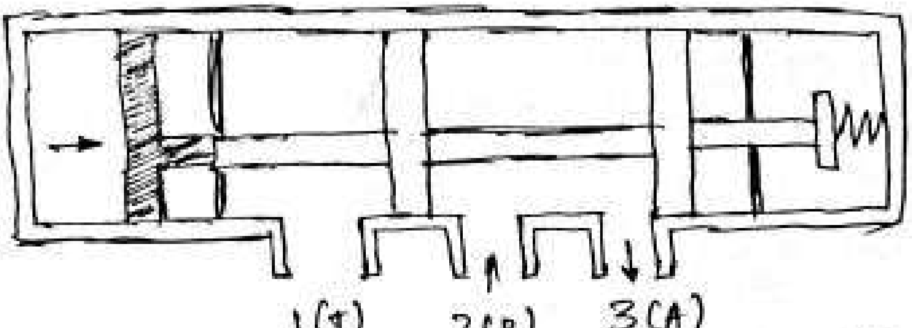
1) For Switching high Current Circuits (3 to 30 kw)
2) TU Switch Control and logical function Circuits

Solenoid Operated DC valve



(a) Unactuated Position

1(T) Exhaust Port
2(P) - Inlet Port from Pump
3(A) - Supply Port to device.



(b) Actuated Position

Fig Solenoid Operated DCV.

In the normal Position fig(a), the Ports 1 and 2 are open i.e the fluid from the Pressurised supply (compressed air) is simply returning through the exhaust port (to atmosphere). That means, there is no fluid supply to the device. When the solenoid is operated, by passing a current through it, it magnetises and pulls the iron core towards it. This in turn moves the spool valve to right fig(b)

This movement now opens the Port 3 and cuts off the Port 1 from 2, causing the flow from Port 2 to Port 3 starts. That means the device is connected to Port 3 starts getting the required Pressurised fluid and gets activated. When the fluid supply to the device through Port 3 is to be stopped, the solenoid is deactivated by stopping the current supply to the solenoid which in turn gets demagnetised. Then the spool is pushed back to its original position by the spring pressure.

Solenoid Controlled Pilot-Operated DCV

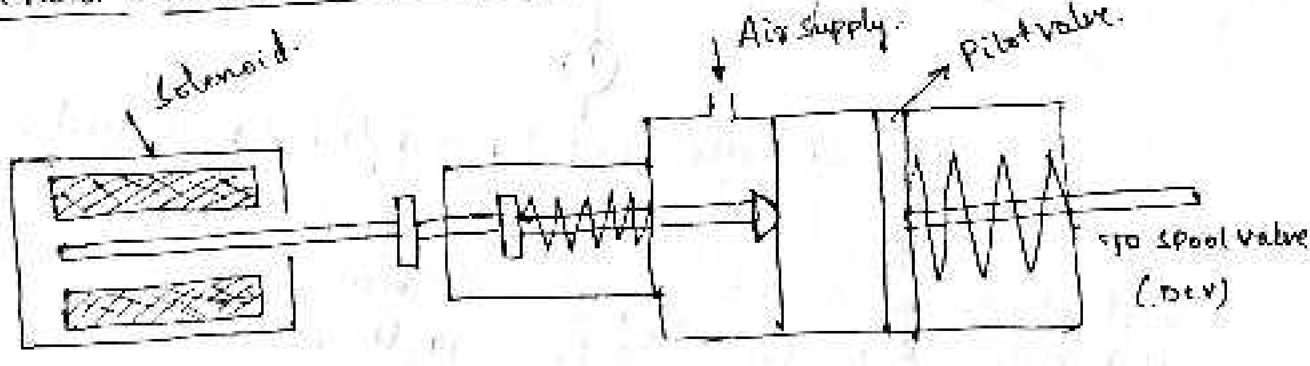


Fig Solenoid Controlled Pilot-operated DCV.

The use of solenoids to operate large DCVs is quite difficult. Since large valves require higher forces to operate, large size solenoids operating on high currents are required. To overcome this difficulty usually the valves are pilot-operated; while solenoids are used to control the pilot-operations. The construction of such a valve is shown in fig. above

In operation, a small capacity solenoid actuates the pilot valve. The pilot valve, in turn, controls the pneumatic supply to the DCV. Since the pilot valve can control large supplies of air, the DC can be actuated easily.

Advantages :- (1) Small capacity solenoids can be used

(2) AC solenoids can be used at low current levels, which improves contact life of the relays

(3) Since low currents are used, the temperature rise is low and thus failure of solenoids (burn-out) is minimum.

Control Circuit for Single acting Cylinder

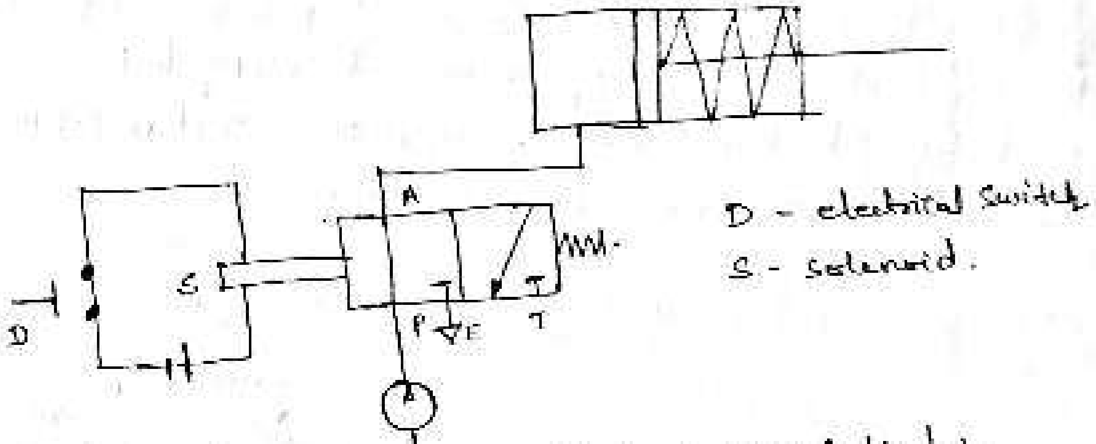


Fig Control circuit for single acting cylinder

In this solenoid controlled 3/2 DCV (3 port : 2 position) is used to actuate the single acting cylinder. It is a spring return cylinder, hence it is actuated by pneumatic power in the extension mode. The solenoid (S) is energised by a manual switch (D), which in turn operates the normally closed (NC) DCV. By this the pressure line is directed to the cylinder port to cause the cylinder actuation. When the switch is released, the valve returns to NC position, by which the cylinder port is directed to the exhaust line. The cylinder then returns back under the spring pressure.

QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS:

DEC 2015/JAN 2016

1) Explain a typical pneumatic circuit with OR logic using shuttle valve.
2) With a neat circuit diagram, explain Electro pneumatic control of a double acting cylinder using a 4/2 solenoid actuated spring return cylinder.
3) Explain the cylinder pneumatic circuit and its motion control diagram.

JUNE/JULY 2016

1) Explain the principle of cascade control system.
2) List advantages of solenoid controlled pilot operated direction control valve.
3) What are flow control valves? Draw graphical symbols for FCV

DEC 2016/JAN 2017

1) Briefly explain the following: i) OR gate ii) AND gate iii) Solenoids iv) Motion Diagrams

JUNE/JULY 2017

1) With a neat sketch explain how OR functions are generated in pneumatic systems.
2) Explain control circuitry for single acting cylinders with circuit diagram.
3) Explain signal elimination using reversing valves.

DEC 2017/JAN 2018

1) Explain with neat sketch of circuit of sequencing of two pneumatic cylinder that can be done by using solenoids, limit switches and valves.
2) Explain with a neat circuit diagram, the working of two step speed control system.

JUNE/JULY 2018

1) Explain the different methods employed for controlling the speed of pneumatic cylinders with neat sketches.

CRASH COURSE – MAY 2017

1) Explain with a neat pneumatic circuit for cylinder sequencing.
2) Explain with a neat sketch solenoid controlled pilot operated direction control valve.

ONE TIME EXIT SCHEME – APRIL 2018

1) Explain OR and AND gates used in pneumatic system.
2) Write a short notes on cascading method.